WHERE EVOLUTION AND RELIGION MEET

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WHERE EVOLUTION AND RELIGION MEET

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WHERE EVOLUTION AND RELIGION MEET

I

INTRODUCTION

No subject of science seems to be more misunderstood by those who are not biologists than the doctrine of evolution. It has been discussed very freely by those who are not informed, and in this way much misinformation has been propagated. It has aroused so much interest, not to say antagonism, that it seems timely to explain it in terms that the general reader can understand. The evolution of the material world, called inorganic evolution, aroused wonder but not apprehension; but when organic evolution came into prominence hostility was aroused, because such evolution involved man.

Why is it that so many people are opposed to the idea of evolution? Clearly this is not because they are in possession of critical evidence that refutes evolution, for practically everyone who has devoted an adequate amount of time and thought to a consideration of the available evidence has become convinced that evolution is a fact. We must conclude, therefore, that those who are opposed to evolution have no very definite understanding of the subject, and base their disbelief on prejudice.

Why does this prejudice exist? Two reasons seem to be mainly responsible. First, it is felt that evolution contradicts the Bible; and we cannot blame those

who are opposed to evolution for this reason, for they have been taught by those whom they have the greatest reason to trust that the Bible is to be relied upon implicitly, and that to question it is sinful. Second, it is the popular impression that evolution requires us to believe that men have descended from monkeys; and this is a shock to one's vanity, for we have a very poor opinion of monkeys. For these two reasons, many people have concluded that the evolution concept is degrading, and hence they will have none of it.

We have no desire to criticise those who hold this impression about evolution for the reasons indicated. Their reactions are quite natural, but their information has been incomplete, and those who base their conclusions on incomplete information are quite commonly in error. When one has been completely informed concerning evolution, he realizes that it does not contradict the Bible in any serious way, but really teaches the same fundamental truths from a different point of view. Furthermore, the careful study of evolution is the very thing which shows us that man could not have descended from the monkeys or apes of today. Ages ago the ancestors of man, monkey, and ape sprang from a common source, and the same may be said of all forms of animal life. The account of how man and all other forms of life emerged from such humble beginnings and gradually developed into the more perfect types of today is far from degrading. Instead it presents about the most ennobling and inspiring concept that we have. Knowing that this is the case, the present authors wish to perform, in some measure, the service of informing the public concerning the present status of evolution.

There is a very significant fact bearing upon the popular prejudice against evolution. Those who maintain that evolution is degrading, actually acknowledge evolution, without recognizing the fact, and in their

life and actions give evidence that they find more interest and inspiration in the evolution concept than in anything else. Evolution is change; organic evolution is that type of change in which a living organism (plant, animal, or man) becomes "better adapted to the environment," develops and perfects the equipment with which the requirements of life are met. In his life every man becomes interested in one or more of a number of enterprises. The real reason that he becomes interested in these enterprises and inspired by them lies in the prospect of his own evolution. Man always cherishes the hope that, in connection with one or the other of these enterprises, he will achieve what he calls "success." This success comes only as the result of his better adaptation to the environment, through his developing and perfecting the equipment with which the requirements of life are met. This is evolution, and it is this evolutionary prospect that interests, inspires, and ennobles mankind. This may be illustrated by a few concrete examples.

The human enterprise that seems to absorb more attention than any other is the attainment of wealth. The interesting and inspiring feature arises from the prospect that one may change from a state of relative poverty to one of relative wealth. In this project one attains success through a better adaptation to the environment, through the effort to develop and perfect the equipment with which he meets the requirements of life; for it can clearly be recognized that the wealth that man strives to attain is an improved equipment with which to meet the requirements of life. Through it all man has been interested and inspired by an evolutionary project; for we all know that the interest and inspiration come with the attainment of riches rather than the mere possession of riches from the start.

Another common human enterprise is the attainment of knowledge. Every student recognizes that here also the real interest and inspiration lie in the process of his own development, in the attainment of knowledge rather than the mere possession of knowledge from the start. Again this is an evolutionary project, a gradual development and perfection of an equipment with which one can better meet the requirements of life.

An athlete is interested and inspired mainly by the prospect of his development, in his change from a condition of relatively less to relatively greater success at some sport; and in any sport the spectators are more interested in the evolutionary phase than in any other feature. The great satisfying thrills come in seeing some favorite athlete improve his technique, in watching some team work and fight its way up from a poor start to a final perfection and success. In any single game we tend to cheer the side that is behind, for we receive the most pleasure in witnessing the evolutionary spectacle which presents itself when the prospective loser struggles through to win out in the end. What thrills us is the process of improvement, the evolution from an unsuccessful (poorly adapted) to a successful (well adapted) position.

Others become devoted to the enterprise of attaining power (for example, political power) among their fellow men. In this matter also the one who gets the real interest and inspiration is the one who, from a humble beginning, gradually works his way into a commanding position. When we read either history or fiction, we are far more thrilled by accounts of some person who has undergone an evolution from obscurity to prominence, than by accounts of one who merely maintained, without further improvement, a commanding position that was bestowed upon him at the start.

In addition to these human enterprises in which the goal to be attained is a rather definite one, there is another common objective which we find running through all of them, or sometimes standing out as an enterprise by itself. This is the attainment of personal efficiency. Whatever one is doing, he is usually interested and inspired by the prospect of doing that thing more efficiently. This involves considerable effort devoted to practice and study, but there is usually ample reward in the satisfaction one receives from the realization that he is more efficient than before. This perfecting of personal efficiency plays a large part in the lives of technicians, professional men, and artists. As in the other cases, the interest and inspiration arise from the prospect of becoming better adapted to the environment, in developing and perfecting that equipment (personal efficiency) with which one meets the requirements of life. Often this improvement of personal efficiency is merely incidental in interest to the attainment of wealth and power, but sometimes we find a person interested merely in the perfection of personal efficiency in itself. This last is plainly seen in some artists and authors who get a real satisfaction out of one of their works that bears witness to improved efficiency, whether or not it may bring them great wealth or fame.

Finally, there is that great human enterprise which consists of the perfecting of one's character. In most cases this is accomplished under the guidance of some sort of formal religion. In this matter we can surely recognize that the inspiring and ennobling feature lies in the hope and prospect of the development and perfection of self along certain "evolutionary" paths that have been outlined by those great thinkers who are the authors of our religion. The inspiration that we get when we "see the light" arises from our first clear vision of this prospect and hope. In other cases people

may be making a conscientious effort to perfect their own characters according to some informal code that they have figured out for themselves, rather than to follow the doctrines of formal religion. In either case one strives constantly to improve his character and personality through attainment of such personal qualities as courage, temperance, and unselfishness. This is evolution. The achievement of these high aims involves a better adaptation to the environment, a development and perfection of the equipment with which one meets the requirements of life. Here the environment is made up mainly of those other human beings with whom we come in contact, and the requirements of life are for a more sympathetic and effective cooperation with our fellow men.

It is this same great evolutionary principle which runs through all human enterprises, which provides the interest and inspiration which we feel for these enterprises. In every case the prospect which engages our attention, which thrills us and stimulates us to our best efforts, is the gradual improvement of ourselves, our institutions, our communities, or our nations toward the goal of perfect adaptation or adjustment to the surrounding conditions. The real significance of that fascinating idea, "success," lies in the evolutionary implication. It is really true, therefore, that mankind, instead of holding a natural prejudice against evolution, actually recognizes it as the most interesting, inspiring, and ennobling concept of all. The same fundamental evolutionary principles which underlie all human enterprise apply also to the whole history of living organisms on the earth, from the very simplest beginnings to the rather highly perfected organisms of today, with man as the culminating achievement, the most perfect organism of all.

The general meaning of organic evolution is that the plant and animal kingdoms have developed in a

continuous, orderly way, under the guidance of natural laws, just as the solar system has evolved in obedience to natural laws. Scientific men who stand for this idea must not be regarded as attacking any creed regarded as sacred. They are simply desirous of proving what is true and useful. Their one thought is to discover the truth, and their method is to observe the facts that will help to disclose the truth. From these facts they draw certain conclusions, which at the time seem consistent with the facts and explain them. Later, additional facts may show that the proposed explanations are inadequate, but the facts remain to be explained. Much misunderstanding has arisen from confusing fact with its attempted explanation.

It should be kept clearly in mind that the fact of evolution is one thing, and any proposed explanation is a very different thing. All of the proposed explanations may prove inadequate, and still the fact remain to be explained. For example, the rotation of the earth is a fact, but it was a long time before any adequate explanation was offered. It is very common to confuse evolution with what is called Darwinism, which is simply a name given to Darwin's explanation of the fact of evolution, one of a number of explanations that have been offered, no one of which may be adequate to explain all the facts. Of course we must first show that evolution is a fact, and then try to explain it, but the two processes must not be confused. It has been too often claimed, when some explanation has proved insufficient, that biologists have given up belief in evolution. Belief in evolution is the working basis of all biologists today, and the discovery that some explanation is inadequate does not induce disbelief in the fact, but is a triumph of biological investigation, which is continually "on the way" toward an adequate explanation.

The purpose of this book is not to unsettle the faith

of anyone in some creed that has proved satisfactory and stimulating to him. We are not seeking to make converts to a belief in the doctrine of evolution. The purpose is simply to give some information that may prove interesting and useful, and that will serve to correct a good deal of misinformation that is current. In other words, we shall try to give trustworthy information, and leave it to the reader to draw his own conclusions. It is simple justice to develop a mutual understanding as to certain gross misconceptions that have crept into the mind of the general public in reference to evolution.

To believe without adequate information is the impulse of those who are unreasonable. It is not characteristic of those who want the facts before belief is reached. We are assuming that our readers will be interested in the evidences of evolution, and will read with an open mind rather than with preconceived notions. The story we shall tell is not fiction, but actual history with which one should become familiar. The fascination of this history is not that it is all pleasant, any more than is human history, but that it portrays continual progress. In other words, the story has an attractive outcome.

It is well to understand what is meant by the scientific attitude of mind, an attitude that has been developing with the progress of science. It is an attitude that seeks to extend the domain of human knowledge, by facing problems frankly and trying to solve them.

In the first place, the scientific spirit is a spirit of inquiry. In our experience we encounter a vast body of established belief in reference to all important subjects. Nothing seems more evident than that all this current belief which we encounter falls under two heads; the priceless result of generations of experience, and heirloom rubbish. Toward this whole body of belief the scientific attitude of mind is one of unprej-

udiced inquiry. The spirit which resents inquiry into any belief is the narrow spirit of dogmatism. The childhood of the race accumulated much which its manhood is compelled to lay aside, and the world needs a thorough going over now and then of its stock in trade. Such work cannot be done all at once, or once for all. Science is continuously at work sorting over this heritage from the past, refuting and discarding those ideas which are false, confirming and preserving those which are true.

Such a spirit is diametrically opposed to intolerance, and it can find no common ground with those who confidently claim that all of our institutions and beliefs have reached their final expression. It is not the spirit of unrest, of discomfort, but the evidence of a mind whose every avenue is open to the approach of the truth from every direction. Like the tree, it is rooted and grounded in the eternal truths that the past has revealed, but is stretching out its branches and ever-renewed foliage to the air and sunshine, and taking into its life the forces of today.

For fear of being misunderstood, we hasten to say that this beneficent result of scientific training does not come to all who cultivate it, any more than the Christ-like character develops in all those who profess Christianity. We regret to say that even some who bear great names in science have been as dogmatic as the most rampant theologian. But the dogmatic scientist and theologian are not to be taken as examples of the "peaceable fruits of righteousness," for the general ameliorating influence of religion and of science is none the less apparent.

In the second place, the scientific spirit demands a real connection between an effect and its claimed cause. People in general do not appreciate how many factors may be involved in a given result. The prevailing belief among the untrained is that any result

may be explained by some single factor operating as a cause. An enthusiast discovers some one thing which he regards, and which perhaps all unprejudiced and right-thinking people regard, as an evil in society, and straightway this explains for him the whole of our present unhappy condition. This particular tare must be rooted up immediately, without any thought as to the possible destruction of the plants which we must cultivate. This habit of considering only one factor when perhaps scores are involved, indicates a very primitive and untrained condition of mind. This is where political demagoguery gets in its most unrighteous work, and preys upon the gullibility of the untrained; and is the soil in which the noxious weeds of destructive socialism, charlatanism, and religious cant flourish.

In the third place, the scientific spirit keeps one close to the facts. There seems to be abroad a notion that one may start with a single well-attested fact, and by some logical machinery construct an elaborate system and reach an authentic conclusion. The result is frequently bad, even when the fact has an unclouded title; but it happens too often that great superstructures have been reared on a fact that is claimed rather than demonstrated. Facts are like stepping stones. So long as one can get a reasonably close series of them, he can make progress in a given direction; but when he steps beyond them he flounders. As one travels away from a fact, its significance in any conclusion becomes more and more attenuated, until presently the vanishing point is reached, like the rays of light from a candle. A fact is really influential only in its own immediate vicinity; but the whole structure of many a system lies beyond the vanishing point. Such "vain imaginings" are delightfully seductive to many people, whose life and conduct are even shaped by them.

The ideals of science may be summarized as follows: They are first, to understand Nature, that the boundaries of human knowledge may be extended, and man may live in an ever-widening horizon; second, to apply this knowledge to the service of man, that his life may be fuller of opportunity; and third, to use the method of science in training man, so that he may solve his problems and not be their victim.

II

EVIDENCES OF EVOLUTION

When we consider the vast array of animals and plants found in nature today, the question very naturally arises in our minds, "How have these many different types of living organisms come into existence; what has been their origin?" This question may be answered in one of two ways.

(1) Some would say that each of the different types of animals and plants had a distinct origin of its own. This assumption would force us to believe that at some time in past history there suddenly appeared upon this planet the first lion. As to what may have produced this lion, or what materials went into the make-up of the beast, these questions are not clearly answered. It is simply assumed that there was in existence some force which could produce in this abrupt manner a fully developed lion where no lion had existed before. In other words, the lion was suddenly produced by "special creation." As an event quite distinct from this first one, there appeared in a similar way the first tiger. Still another event was the sudden appearance of the first leopard, and so on for every one of the many types of animals and plants that we see around us today. Each was produced quite separately, so that no two types are in any way related to one another. The agent which acted to bring about these results, the method of the creations, and the materials used are not explained.

(2) Others would answer the question as to the

origin of the animals and plants of today in quite a different manner. We are perfectly certain of the fact that today, and for as long as man can remember, individual animals and plants have come into existence in only one way, through descent from other animals and plants. The parent begets the offspring by means of a process of reproduction, and we have every reason to believe that this same process has been repeated innumerable times in the past, throughout a period of countless thousands of years. During this time there has been ample opportunity for some of the descendants of the original individuals gradually to become modified so that they no longer are exactly like their original ancestors.

For example, there was in existence, many thousands of years ago, a single type of cat-like animal. One group of its descendants very gradually, through the lapse of countless generations, became modified into the lion of today. Another group of descendants of this same ancestral type, through very gradual changes that occurred during the course of thousands of years, finally developed into the tiger. Still another line of descent from this same beginning resulted in the leopard of today. Hence all of the various types of cat-like animals that we see today are really related, for they have all sprung from the same source, a common ancestor that lived some time in the dim past.

According to these same principles, it is believed that all animals and all plants are the descendants of one or a very few original types that existed in the past. Throughout the ages there have been taking place gradual changes among the many descendants of the original types, a process of "evolution" has been going on, and it is in this way that we may account for the existence of so many different types of plants and animals today.

It is this second view that has been accepted by

scientific men. Special creation, they believe, is much less reasonable, much less successful in fitting the known facts of nature, than the evolution concept. For many years biologists have been discovering additional bits of evidence which demonstrate that evolution is the true story of the past history of our animals and plants. Such an enormous mass of evidence has by this time been accumulated that, in scientific circles, evolution is regarded no longer as a mere theory, but as an established fact.

We shall present some of this evidence, and see why it is that scientific men are convinced of the truth of evolution. The evidence is obtained from some of the actual facts of nature, facts which become very significant if we accept the evolution concept, but which are quite meaningless if we do not. By no means all of the available evidence will be discussed, for it requires considerable training in biology to appreciate some of the lines of evidence.

EVIDENCE FROM ANIMAL STRUCTURES

When we make an examination of the organs and tissues of that vast array of animals which are equipped with back-bones, we find that there is one general body plan which prevails through all of them. The skeletons of the horse, the dog, the cat, and of man show a fundamental similarity, and differ only in certain minor details. Certain bones may in some cases be relatively longer or thicker or have a slightly different general outline, but for practically every bone in one of these types we find a corresponding bone in the others, and the general plan of arrangement is essentially the same. The same feature appears in connection with the other tissues also. A muscle has the same fundamental make-up in each case, shows the same method of attachment to the bones, and functions according to the same principles. Certain

muscles are in some cases more highly developed than in others, but the set of muscles with which the animal is provided is essentially the same in each case. The same similarity of body plan appears in connection with the nature, arrangement, and method of functioning of blood-vessels, glands, nerves, and even in connection with the very highly specialized tissues of the brain. One who makes a study of these facts finds it much easier to believe that all of these animals are the modified descendants of one original ancestral type, which possessed this general body plan, than to believe that each had a separate origin as the result of special creation.

There is another feature, frequently encountered in the study of animal structures, that provides a rather striking form of evidence for evolution. In many animals there appear certain organs which are clearly underdeveloped and useless. There is a type of snake that possesses hind limbs. These structures, however, are so underdeveloped as to be scarcely visible from the outside, and are never used in any way by the snake that possesses them. The whale is endowed with the same apparatus of the internal ear as are those of our higher animals which live upon the land. This apparatus is adapted to hearing in air. In the whale it is very much reduced and degenerated and is not used for hearing. The eye provides the power of sight to those animals that live in the light. Animals that spend their lives in dark caverns frequently possess degenerated eyes which are utterly useless to them. There appear countless examples of such underdeveloped and useless organs among the many members of the animal kingdom.

How can such things be accounted for on the basis of special creation? When these animals were created, why should they have been equipped with organs that were of no use to them? The evolution concept, how-

ever, provides a ready interpretation for these matters. The underdeveloped and useless structure which we find in one animal is represented by an organ which is fully developed and very useful in another animal. The two types of animals are related, are descended from a common ancestor. The common ancestor was endowed with the organ in question in its fully developed and useful condition. Some of the descendants retained this organ in the same condition. Another line of descendants, however, encountered changed conditions of life, such that this particular organ was no longer useful. As a result the organ was allowed to dwindle away in successive generations until it had reached a very much reduced condition.

This interpretation would be applied as follows to the examples which were used. The snake descended from an ancestor which had functional hind limbs, but had dispensed with the use of the limbs for so many generations that they had degenerated almost to the vanishing point. The whale is a relative of our higher land animals. The original common ancestors, which lived on land, possessed an ear which was adapted to hearing in the medium of air. The whale, submerged for countless generations in the waters of the sea, gradually lost the use of this ear, so that its various parts degenerated. Similarly the blind animals of dark caverns are the modified descendants of forms which lived in the light and possessed fully developed eyes. It can be seen, therefore, that these underdeveloped and useless organs, "vestigial structures" as they are commonly called, find their significance, their interpretation, only in the evolution concept.

Still one more phenomenon, often encountered in the study of animal structures, provides very impressive evidence for evolution. The subject of "embryology" considers the development of animal bodies from the egg to the adult condition, noting every stage in the

process. In many cases these developing bodies (embryos) show structures that disappear before maturity, but often these are structures that persist in other animals and are features of the adult body. It is hard to imagine why structures appear in the embryo, only to disappear, unless in ancestral forms these structures persisted and were used. In other words, it is impossible adequately to account for such cases on the basis of special creation; the only reasonable interpretation is that which is provided by the evolution concept.

In some cases, usually in our very highest animals, the developing embryo exhibits quite a series of these structures that disappear before maturity. The very young embryo will possess temporarily a structure which appears in the adult body of a very remote ancestor. This structure will then be lost, and the older embryo will exhibit some other temporary structure. In this second case the structure is one which appears in the adult body of a more recent ancestor. By means of a series of this sort, the developing embryo may summarize the evolutionary history of the race. The young human embryo exhibits the gills of an ancient fish-like ancestor. Soon these disappear, and the older embryo develops a tail. How can such things be explained by special creation? Is it not evident that this provides a record of our evolutionary descent?

The conclusions suggested in this case are really the same as those derived from the vestigial structures mentioned before as occurring in adult bodies. In fact, these temporary structures of the embryo are merely vestiges that have disappeared from the adult body, but still linger in the embryo.

It can be seen, therefore, that a study of animal structures provides three strong lines of evidence for evolution: the evidence from comparative anatomy, the evidence from vestigial structures of adult bodies, and the evidence from the temporary vestigial struc-

tures of the developing embryo. A study of plant structures would reveal evidence of a similar sort, but in that case the evidence would be less striking, for the illustrations would be less familiar to the reader.

EVIDENCE FROM THE GEOLOGIC RECORD

During the early history of the earth, the continents of olden times were traversed by a network of rivers. These rivers were scouring away at the land surfaces and carrying the resulting mud along with them. At the mouths of the rivers, where the current was suddenly checked, this sediment was deposited. Year after year this continued, until vast quantities of mud were accumulated in such places. Eventually, through the pressure of materials above, this mud became transformed into rock. In this way were produced the sedimentary rocks of an early geologic age. During later ages rocks continued to be formed in the same manner and the sedimentary rocks of a later age were always deposited on top of the sedimentary rocks of a preceding age. Today we find many layers of these sedimentary rocks, and we know that the sequence of the layers from bottom to top represents the historic sequence of the geologic ages, from the earliest times down to the present.

Now when the mud was deposited, very frequently there were deposited with it the dead bodies of certain plants and animals which inhabited the earth at that time. These bodies, imbedded in the mud, often became petrified, so that they were preserved when the mud changed to rock. Even when the plant and animal bodies were not successfully petrified, they often left behind them casts or impressions which persisted when the mud hardened. So it is that today, upon breaking open the sedimentary rocks, we encounter the fossil remains of those plants and animals that inhabited the earth at the time that the rocks were being formed.

Very often these fossils consist of mere fragments, but in other cases they are surprisingly perfect. They have been studied very carefully, and in this way the plants and animals of one age have been compared with those of another. If evolution is true, this geologic record should bear testimony to the fact, and should reveal a definite story of the successive steps that have taken place in the past evolution of our plants and animals.

In this matter our expectations have been more than realized. This impressive record of the rocks shows that during the earliest known period plants and animals lived that were entirely unlike those of today. In the next period, different kinds of plants and animals appeared, usually some of the old kinds holding over. As period succeeded period, new kinds of plants and animals appeared, and the old kinds disappeared, until, in the later fossils, resemblances to the present plants and animals can be recognized. These resemblances gradually increased, until finally, without any sensible break, our present plants and animals appeared. In short, a tremendous stretch of history confirms the evolutionary idea that plants and animals have been changing from the first, and that the modern forms are the modified descendants of these earlier forms. Probably the geological record comes as near being a demonstration of the fact of evolution as anything could be short of an actual experiment.

One of the classic examples is provided by the evolutionary history of the horse. In the rocks of an early geologic age there appear fossils of an interesting animal which had five toes and was only about eleven inches in height. Among the fossils of the next succeeding age is an animal very much like this first one, except that it is a little larger and has lost some of its toes, having now only four toes on the front feet and three on the hind feet. As we pass successively through

the ages we find a clear line of descent from these original forms. Gradually the descendants become larger, their limbs being elongated and their total weight increased. At the same time they lose their toes, until finally only the middle digit on each foot is preserved, with but tiny vestiges of some of the others. Along with these changes many others are taking place. The grazing mechanism is perfected; the head and neck gradually elongated and some of the teeth equipped with complex grinding surfaces. As a final culmination of this long line of descent, there appears the horse of today. It is a clear story from the beginning, demonstrating how the horse has descended through a series of gradual modifications from an original ancestral type that was quite different.

What is true of the horse can be demonstrated as well for a number of other animals. Long lines of descent through the geologic ages can be traced for the elephants, the camels, and even man, though in this last case, as might be expected, the record covers a shorter period of time. What can be shown for animals can be shown for plants also. How can this geologic record be accounted for on the basis of special creation? What could be more clear testimony to the fact of evolution?

EVIDENCE FROM CULTIVATED PLANTS AND DOMESTICATED ANIMALS

From the evidence that has been considered up to this point, man concludes that evolution has taken place in the remote past. We shall now consider certain situations in which man has actually seen evolution taking place during the recent past.

When man first started to practice agriculture, he chose for this purpose some of the wild plants and animals that were the best suited to his needs. During the centuries which followed, these types of plants and

animals gradually became changed, gradually became better suited to man's needs. Just how these changes were brought about will be considered in some of the later chapters. At present we are interested merely in the fact that evolutionary changes actually did take place under man's observation. Today we have many very highly-developed varieties of cultivated plants and domesticated animals, and, in many cases at least, we know what were the wild ancestral types from which these have descended. Comparison of the ancestral types with the present cultivated or domesticated varieties reveals vast differences, and we know definitely in these cases that the differences have been brought about by a gradual evolution.

Consider the many exceedingly different races of dogs that have all been bred from one wild stock. Consider also the many varieties of cattle and of chickens. The present-day types are quite different from each other, and quite different from the wild original ancestor from which they have all descended. Even more striking changes have been brought about among cultivated plants. Few people realize that the cabbage, the cauliflower, the kohlrabi, Brussels sprouts, kale, and collards are all descendants of the same wild ancestral type. These forms are very different from each other, and very different from their common ancestor, the wild cabbage, which is still growing in some places. These and many other modifications have been brought about under man's observation. In these cases we have seen evolution taking place. According to the special creation concept such results should be impossible, but we know that they are possible because we have seen them take place.

There are also a number of other lines of evidence for evolution. These others, however, will not be discussed here, for the reader without biological training would not fully appreciate them. We believe that the

few lines of evidence that have been presented are by themselves sufficiently convincing. An even greater conviction should be developed by the succeeding chapters, in which we shall turn our attention to the question of how the evolutionary process has taken place.

III

LAMARCK'S THEORY OF USE AND DISUSE

During the last decade of the eighteenth century, three distinguished men had simultaneously and independently proposed the first explanation of evolution. The evidences that evolution might be a fact had been accumulating so rapidly that some attempt to explain it was inevitable, and this first attempt came from the three leading countries in scientific work. The three men who proposed the same explanation were Goethe of Germany, St. Hilaire of France, and Erasmus Darwin (grandfather of Charles Darwin) of England.

The explanation may be called the "theory of environment." It had been observed that birds change their plumage and animals their fur with the changing seasons, and this suggested that animals respond to environment in a striking way. Animals were thought to be plastic and moulded by environment, as clay may be moulded by the fingers of a potter. In this explanation, therefore, environment was regarded as an external agency impressing itself on the bodies of animals, and changing them to fit the environment better.

Of course there is such a thing as response to environment, and this was perhaps the first natural explanation of evolution, but it was soon found to be too superficial to be at all adequate, so that it did not survive long as a real explanation. A more definite and thoroughgoing explanation was to be desired. Such an explanation was provided at the opening of the nineteenth century by Lamarck.

Lamarck has been called the "founder of organic evo-

lution," because he was the first to develop what may be called a definite, well-organized doctrine; in other words, a system of belief in reference to evolution.

Lamarck was a Frenchman, the period of his life extending from 1744 to 1829. He became a leader in botany, publishing a manual of the flora of France, which became the standard manual for that country. Later he became interested in zoology, especially the fossil mollusks, and it was this study that led him to his conclusions concerning evolution.

Lamarck offered his explanation at an unfortunate time for any fair consideration. The dominant French naturalist at that time was Cuvier, who bitterly and sarcastically opposed Lamarck's ideas. Cuvier did not believe in evolution, and as he had the confidence of the public, Lamarck's attempt to prove the fact of evolution and its explanation made no headway. He was more than a generation ahead of his time, and hence his great reputation came long after he was dead.

Thoroughly convinced that evolution was a fact, Lamarck sought to explain how the evolutionary changes might be taking place. Although the information at his disposal was very meager, as compared with what is now available to biologists, Lamarck devised an ingenious and logical theory, which has exerted a profound influence upon biological thought ever since. This was the theory of use and disuse. In brief the idea is this. When an animal uses one of its organs to an unusual degree, that organ is thereby developed; while if the organ is not used at all, it degenerates. Such modifications may be transmitted to the progeny, thus making it possible for the effects to accumulate over a number of generations. In this way an organ may in time become so highly developed, or so completely degenerated, that the animal possessing it is really of quite a different type or species from its original ancestors. This constitutes evolution.

The best way to explain Lamarck's ideas is by the use of a concrete example. Using Lamarck's theory, we may show how one type of animal gradually gives rise, among its descendants, to a type which is quite different. If this can be demonstrated in one instance, presumably it will hold true for other instances as well; if the theory can explain the evolutionary changes that have taken place in connection with one organ or character, presumably it can also account for other evolutionary changes. While the example which we shall use may be open to considerable criticism on the ground of scientific details, it has the advantage of dealing with familiar material, and will be quite suitable as an illustration of the workings of Lamarck's theory.

The proposition is to explain how the giraffe evolved from a horse-like ancestor, how the long fore-limbs and neck of the former could have arisen from the short limbs and neck of the latter. Lamarck accounts for such a change in the following way. The horse-like ancestors lived originally in a region composed of meadows, where their food was provided in the form of grass and other small herbaceous plants. A certain group (not all) of these horse-like forms migrated to another region. This migration might have been a voluntary "exploration," or it might have been a case of having been driven from the original district by certain predatory animals that abounded there. In any event, a group of horse-like forms came to live in a new district, and this new district had quite different characteristics from the old one. It was a dry desert region, with no grass or other small herbage, and only an occasional tree. Thus these animals have been thrown into quite different surroundings from the old. Their *environment has changed,* and this change in environment is to bring very important consequences.

Facing this new environment, the animals find that

their customary source of food is no longer present. The only available source of forage is the leaves of occasional trees, and these leaves are rather too high to be reached conveniently. The animals are starving, in dire need. Under the circumstances, what they particularly need is to be able to reach up and browse upon the foliage of the trees above them. Thus the change in environment has resulted in a *new need*, a need which had never been experienced before. The logical consequence of this new need is the creation of a *new desire* in the animals that are experiencing the need, a desire to reach upward to the only food that is available. As a result, the animals try to reach the leaves, they make a *conscious effort* to stretch upward. This conscious effort sets in operation those forces which are to bring about evolution.

Just as the blacksmith by constant exercise develops a mighty forearm, so the horse-like animals by constantly stretching upward actually lengthen their neck and fore-limbs. These organs are *developed through use*, developed as they had never been developed before, simply because they had never before been exercised in this particular way. Perhaps the animals may, during their lifetime, increase their height an inch or two through this special form of exercise. Of course they are not yet giraffes, but they have taken the initial step.

At this point Lamarck makes an assumption, an assumption which seems quite logical on the face of it. Characters which have been acquired by parents are passed on to the progeny. The slight gain in height which has been made by the animals of the first generation is passed on to the animals of the second generation. This is *inheritance of acquired characters*, and it is through this that Lamarck explains evolution. The second generation of horse-like animals, endowed at the beginning with the slight gain in height which

they have inherited from their parents, continue to live in the same environment. Consequently they are actuated by the same motives as before, and will themselves stretch upward for forage. As before, this stretching will result in a slight increase in length of neck and fore-limbs, but now this increase in height will be added to the initial increase that had been inherited from the parents. The acquisitions of the second generation are added to those of the first, and through a series of generations these modifications are *gradually accumulated.* So it is quite clear that, although any one generation might gain but an inch in height, in the course of enough generations there will result the fully-developed giraffe. The horse-like ancestor has given rise to the giraffe descendant; an old species has given rise to a new one; evolution has taken place.

One is struck by the apparently quite logical sequence of cause and effect relationships that appear in this theory. A changed environment brings a new need. The animal responds to this new need by a new desire and a conscious effort to satisfy the desire. The conscious effort inevitably results in the unusual exercise or use of certain organs, and with this use the organs are developed. Whatever gain this development brings is passed on to the progeny, who in turn add a further gain along the same lines. As a result of this gradual accumulation, a new species sooner or later results, and thus we have evolution.

It is to be noted that this evolution is always adaptive. The new species is better adapted to cope with its environment than was the old species; the giraffe has a better equipment to carry on a successful existence in the desert region than had its horse-like ancestor. It is also evident, however, that what amounts to an adaptive change in the new desert environment would not be adaptation in the old meadow environment. In the old environment the horse-like ancestor

would doubtless be better adapted than would the giraffe descendant. Hence we must conclude that not all the horse-like animals were changed into giraffes, but only those which were thrown into the desert environment. Where there was but one species before, there now exist two. Whereas the original group of animals could successfully occupy only one type of region, their descendants are now able to spread over both the meadows and the deserts. Thus evolution does not (necessarily) result in a supplanting of the old species by the new, with an extinction of the former, but results in the multiplication of species, along with the conquering of new territories.

This illustration of Lamarck's theory shows how adaptive evolution may come through the greater development of certain organs, a type of change that would be called progressive. The theory may also be employed to explain how adaptive evolution may in other cases result from the less development or degeneration of certain organs, a type of change which might be called retrogressive. Lamarck illustrated this type of case by the evolution of the snake. Snakes are descended from animals that had legs. A certain group of these animals was thrown into a new environment where new needs were encountered. In this case it was necessary, either as a means of flight from dangerous foes or as a means of pursuit of elusive victims, to creep through narrow crevices. Feeling this need, actuated by the desire to accomplish this, and making a conscious effort to do so, the ancestral animals spent their time at the exercise of wriggling through narrow crevices, and thereby allowed their legs to fall into disuse. As a result of this disuse, this lack of exercise of the limbs, those members degenerated somewhat during the first generation. The second generation started with the heritage of slightly underdeveloped limbs, and allowed the limbs to degenerate still further.

The final result of this accumulation of effects was the complete loss of the limbs, the production of the snake.

Lamarck's theory usually appeals to those courageous people who enjoy or approve of personal responsibility, for Lamarck would encourage us to believe that the fullest development of future generations can come only through exercising our capacities toward a better adaptation of ourselves to our environment. Simply because it provides this inspiring rule of conduct, however, we must not conclude that Lamarck's theory is necessarily the true explanation or the only explanation of evolution. Other explanations of evolution likewise provide inspiring rules of conduct, and perhaps assign a more important mission to those who cannot have descendants, or can no longer have descendants.

This was the theory which Lamarck presented in 1801, at a time that his biological colleagues did not even believe in the fact of evolution. These colleagues, blindly holding to the old conservative views of special creation, and doubtless moved by petty jealousies, immediately attacked Lamarck with a storm of ridicule and abuse. Prejudiced from the start against the new theory, these other biologists magnified every little flaw in the illustrations which Lamarck used, and refused to recognize the real truth and value which lay in Lamarck's basic propositions. This wholesale antagonism practically ruined Lamarck's influence in the biological world, and he died in obscurity. It was a later generation that appreciated his work.

As a matter of fact, there were two big difficulties with Lamarck's theory. In the first place, Lamarck laid what was really unnecessary stress on the operation of conscious effort as a necessary part of his theory. This was unfortunate, since biologists refuse to recognize the possibility of conscious effort in plants and in primitive animals. Automatically then Lamarck's

theory becomes restricted to accounting for evolution only among higher animals. A modification of the theory is necessary before the other cases can be included.

The other objection to Lamarck's theory is a much more serious one. It is quite essential to the theory that acquired characters be inherited. Otherwise there could be no further progress than the slight gain made during a single generation, and this would not be sufficient to bring any substantial evolutionary advance. It is clear, therefore, that Lamarck's theory provides an explanation of evolution only if inheritance of acquired characters can take place. As a matter of fact, during the century following Lamarck, the most reliable evidence that was collected on this point seemed to indicate clearly that inheritance of acquired characters never takes place. For this reason the theory was discarded by most biologists. Recently Lamarck's theory has been revived in a modified form, as will be described in a later chapter.

In spite of the poor success of Lamarck's theory, he must be given credit for having presented the first comprehensive theory on evolution. His theory failed as an explanation because it could not meet the two critical objections that have been mentioned. It remains to be seen whether these objections can be met any more satisfactorily by the later theories.

IV

DARWIN'S THEORY OF NATURAL SELECTION

THERE is no more famous name in the history of biology than that of Charles Darwin. He was born in 1809, sixty-five years after the birth of Lamarck, and died in 1882. He was born at Shrewsbury, England, studied for a short time at Edinburgh University, and then went to Cambridge, where he graduated in 1831. At that time Professor Henslow, a distinguished botanist, was at Cambridge, and he stimulated the interest of young Darwin in the world of life. Through the influence of Professor Henslow, Darwin was appointed naturalist of the famous British expedition around the world, in the ship Beagle. This expedition started in 1831 and returned in 1836, much of the time being spent in South America and the adjacent islands. It was his world-wide observations during the five years of this expedition that sowed the seeds of Darwin's ideas concerning evolution. The long voyage ruined his health, and during the rest of his life he could work only a limited amount each day, living in seclusion at his country place at Down.

For over twenty years Darwin worked at his explanation of evolution, and in 1858 he received from his friend Alfred Wallace, who was then traveling in the East Indies, a manuscript containing exactly the theory he had worked out. With characteristic generosity, Darwin decided to abandon his work, and give precedence to Wallace's paper. Fortunately, however, certain of Darwin's scientific friends, who knew of his

work, urged him to present his own results along with those of Wallace at the same meeting of the Linnean Society in 1858. These two papers, therefore, were read at the same meeting, and when Wallace learned of the situation, he withdrew from the field, recognizing Darwin's prior claims on account of his many years of work. It was in 1859 that a full account of Darwin's explanation was published in his "Origin of Species," and it at once aroused the greatest interest, not only because it came at a "psychological moment" to attract attention, but also because of the extraordinarily able championship of Huxley.

Darwin makes three distinct contributions to the cause of evolution and to biological science in general. In the first place, his work exemplifies the perfection of a certain method of research, the method of observation and inference. Darwin's observations were about as extensive in space as would have been possible, covering practically the whole globe; in time they were likewise quite as extensive as could reasonably have been demanded, for Darwin studied his problem intensively for 20 years before publishing his conclusions. In the matter of thoroughness, his methods leave nothing to be desired. The account of his years of conscientious investigation furnishes a much-needed stimulus and a warning to other investigators who are in danger of carrying on hasty and hence unreliable research.

Darwin's second contribution was his greatest one, and the one for which he has become deservedly famous. He was the first author who was successful in carrying the evolution idea before the general public. This was not accomplished through Darwin's direct influence, for in his own writings he did not really address the general public. Darwin's writings, however, were received with great enthusiasm by a number of very influential biologists, and it was these

men who preached the doctrine of evolution very widely before general audiences. Under the circumstances it is not surprising that the public got the impression that Darwin was the author of the idea of evolution. This is strictly untrue, for Lamarck and many others had recognized the fact of evolution before Darwin's time, as Darwin himself clearly acknowledges. But although Darwin cannot justly be credited with authorship of the idea, he is at least the one who was primarily responsible for spreading the idea. That in itself was a great service, for it brought substantial benefits to many lines of human thought, as we shall see later.

In this connection it should be pointed out that Darwin was a great deal more fortunate than Lamarck. Lamarck attempted to present the evolution idea at a time when the public was not ready to receive it; hence the enterprise was a failure. By Darwin's time, however, sufficient progress had been made in human thought, that the world was ready for the evolution idea; since he presented evolution at this psychological moment, the scientific public received it with great favor.

Darwin's third contribution was the theory of Natural Selection, by means of which he attempted to explain evolution. How successful an explanation this proved to be we shall see later, but it must at all times be kept clearly in mind that any objections to Darwin's theory are not objections to the fact of evolution. As has been said, every explanation of evolution that has ever been proposed may prove unsatisfactory, but the fact of evolution will still remain to be explained. As we present Darwin's theory of Natural Selection, we should consider whether it is successful in overcoming the two serious objections that were raised to Lamarck's theory. In other words, we should see whether Darwin explains evolution without requiring

conscious effort or the inheritance of acquired characters.

At the basis of Darwin's theory lies the tendency to a *geometrical ratio of increase* that is present in all plants and animals. If the human race were to breed at the fairly conservative rate of 4 children per family and a generation every 25 years, if all the children themselves survived and had families, and if death by accident, disease, or starvation were eliminated, the descendants from a single pair at the end of a thousand years would amount to a million million individuals. Most plants and animals have a much higher rate of increase than this, for the generations are short and a great number of progeny is produced each generation. A famous example is provided by the rotifers, animals so tiny as to be barely visible to the naked eye. If these animals were allowed to breed at the normal rate and it were possible to rear all of the progeny, a single pair would produce within a year "a solid sphere of organic matter with a radius greater than the probable limits of the known universe." It is quite obvious that these expectations are never realized, and the reason is that death by accident, disease, and starvation is constantly taking place to check this prodigious rate of increase.

The bearing of this phenomenon on Darwin's theory becomes evident from the following considerations. In a certain meadow there are growing a thousand plants of a certain kind. Each plant produces one hundred seeds. Each seed has the power of producing a young plant the next season. On this basis we might expect to find 100,000 plants occupying the meadow during the following year. Now there is good reason to believe that each of the 100,000 seeds starts to produce a young plantlet at the beginning of the year, but by the end of the season we find that only about a thousand mature plants are present, approximately the

same number as the year before. Why? Because in that locality there is only enough room and means of subsistence to support a thousand plants of that kind. Out of the hundred thousand young plants that started the season, 99,000 have perished through accident, disease, or starvation. "Death is the rule, life the exception." There is an *equilibrium of species,* approximately the same number of individuals of a species being present in a given locality year after year.

How can this phenomenon operate to bring about evolution? Darwin interprets the situation as follows. If we are to consider any group of individuals of the same species we find that no two of them are exactly alike. We immediately recognize that this proposition is true of the human race. Out of the many thousands of men that we have encountered during our experience, we have never found any two that were absolutely identical, indistinguishable. Even twins can always be distinguished after critical examination. What is true of men is also true of plants and animals, although we may not at first recognize it. It would be impossible to find two oak trees or two cats that would be indistinguishable upon careful examination. In other words, in all living organisms there is *variation* such that no two individuals are ever exactly alike.

Since this is true, it means that the hundred thousand young plants that we were considering were all somewhat different with respect to one character or another. One thousand out of the total hundred thousand survives. Which thousand is this to be? Will the matter be decided entirely by chance? To a certain degree, but not entirely. If one hundred plants start to grow where there is only enough space or food available for one of them to mature, it is evident that a sort of a competition will be set up among these one hundred individuals, a *struggle for existence,* in which one indi-

vidual will succeed while the rest perish. Under the circumstances, which one of the hundred will be the one to survive? If all the hundred individuals are identical, it will be a matter of chance which one survives. But we know that they are all slightly different with respect to one characteristic or another. One of them might be endowed with the ability to grow a little faster than the others. It would then get a better start than its competitors, raise its head above the rest, and hence get a fuller exposure to light, which is essential to plant growth. Having this decided advantage, the fortunate plant would continue to thrive, and, by casting its shade over the others, would eventually crowd them out. Again, one of the plants might differ from the rest by having slightly longer and more vigorous roots. It would then get from the soil more of the water and salts which are essential to plant growth, and, developing a stronger growth than its competitors, would be the successful one of the hundred. Whenever competition is set up in this way, it is the stronger individual that is successful, while the weaker ones perish. The successful individual is the one which happens to be a little better adapted to its environment than are the others. As Darwin puts it, there is a "survival of the fittest," a *natural selection* of those that are the best equipped to meet their living conditions, with an elimination of the others. It is this inevitable natural phenomenon that brings about evolution.

The exact workings of the Darwinian principles in the production of a new species from an old may be illustrated by the same imaginary case that was used before to illustrate Lamarck's theory. Let us see how the Darwinian theory can account for the origin of the giraffe from a horse-like ancestor by means of the principle of natural selection, without calling upon any of the conscious effort or inheritance of acquired char-

acters which proved to be the objectionable points in Lamarck's theory. To make the same start as in the other case, a group of the horse-like animals is thrown into a new, desert environment where the only substantial forage is provided by the foliage of trees. Although these animals all belong to the same species, there occur slight individual variations with respect to practically all their characteristics. The particular characteristic that is significant in the present connection is the matter of height. A few of the animals have slightly longer necks and fore-limbs than have the others. Food is limited; only the lowest branches of the trees are within the reach of any of the animals. The tallest of the animals are successful in reaching this food, while the others starve to death.

Since the tallest animals are the only ones to survive, it follows that they are the only ones to reproduce. As a result, all of the animals of the second generation are the progeny of parents that were slightly taller than the average of the species. To put the matter in exact terms, let us say that the average height of the first generation was six feet, but that some of the animals were as tall as six feet two inches, while some of the others were only five feet ten. It was the individuals of the former group that survived and reproduced. The individuals of the second generation were, therefore, the descendants of six-foot two-inch parents. What then will be the average height of the second generation? Is it not reasonable to suppose that that average height will be six feet two? Is it not a matter of common experience that the slight peculiarities that distinguish any given parents from the general mass of the population will be passed on to their progeny? Surely Darwin is quite justified in concluding that the animals of the second generation will show an average height of six feet two inches.

This further conclusion also seems entirely justified.

Just as the individuals of the first generation varied in height around an average of an even six feet, so it follows that the individuals of the second generation will *vary* in height around an average of six feet two; that is to say, some of them will be as tall as six feet four, while others will be only an even six feet.

These are the characteristics of the population of the second generation, a population which now proceeds to face the same conditions and to enter into the same sort of a competition or struggle for existence as did the parents. Still the food is limited, and the taller ones have a decided advantage over the others in procuring it. As before it is the tallest group, the six-foot four individuals, that is successful in the struggle, while the rest perish. It follows that the individuals of the third generation, since they are the descendants of parents that were six feet four in height, will vary around the average height of six feet four, some of them being six feet six, while others are only six feet two. Generation after generation the same forces operate. The average height of the species *gradually increases,* because it is always the tallest individuals that have an advantage in the struggle for existence. Eventually the characteristic height of the giraffe is attained and a new species may be said to have been evolved. The same evolutionary result has been obtained as under Lamarck's theory, but without the operation of conscious effort or the inheritance of acquired characters.

To summarize: The capacity for geometrical ratio of increase, which appears in all living organisms, tends to bring into the world a greatly increased number of individuals with each generation. Since there is not enough space or enough food to go around, there results a competition or struggle for existence among the individuals. One of the results of this struggle for existence is to kill off all but a fortunate few, and thus

maintain a constant number of individuals, an equilibrium of species, generation after generation. Under special circumstances there may be exceptions to this, but the exceptional situations are, at best, only temporary, and do not affect the adequacy of Darwin's theory. The other result of the struggle for existence arises from the fact that there are never any two individuals which are quite identical, there is always variation. Hence, in this varying group of competing individuals, it is the fittest that survive, those which are the best adapted to their environmental conditions. It is these individuals that produce the next generation. The average fitness of the next generation is the same as that of the parents, but some few of the progeny are even more fit than were the parents. Again it is this group of the most fit that survives, so that there is a continuous though gradual gain as the generations go on. Eventually enough change has been made to bring into existence a new species.

Not only in the case used as an illustration, but in practically all other cases as well, the Darwinian theory can be used just as successfully to explain evolutionary change as can the Lamarckian. As before, we find that the evolutionary machinery operates to produce a type of animal (or plant) which is better adapted to the environment than was the ancestral type. And, as before, it is clear that the same change which means a more perfect adaptation in one set of environmental conditions would not be a more perfect adaptation under another set of environmental conditions. The general result is to produce two species where but one existed before, and to increase the territory that may be occupied.

There is a very impressive type of evidence which has been used as confirmation of Darwin's theory, and at the same time may be used to illustrate how adaptation to one set of conditions is not successful adapta-

tion to another set of conditions. Nature has not been the only agent to bring about evolutionary change through a constant selection of better adapted individuals. Man himself has acted in this same capacity, and with considerable success. For many centuries man has been carrying on selection with his cultivated plants and domesticated animals. This selection has perhaps been even more rapid in producing evolutionary change than natural selection, for here it is even more certain that it will always be the best adapted individuals that will be the progenitors of the next generation. The great difference lies in the basis of selection. Nature always selects those individuals which are the best adapted to the environment when grown in the wild, under natural conditions, while man always selects those individuals which are the best adapted to his own needs when grown under conditions of artificial cultivation. Starting with a given type of plant, nature would be likely to produce by her selection a type that could live successfully in poor, dry soil, but would not produce a great weight of seed or fruit. Starting with the same type of plant, man would produce by his selection a type which would bear a great weight of seed or fruit, but which would be adapted to living only in the fertile, irrigated soil which he provided for it. Starting with a given type of animal, nature would be likely to produce a type which could run and fight, but did not develop a great weight of meat on its bones. With the same start, man would develop a heavy, sluggish variety that would be very poorly adapted to running or fighting. In almost every case the adaptation to man's needs is quite different from adaptation to nature's demands. Furthermore, if man were to allow some of his cultivated plants or domesticated animals to return and live under natural conditions, these forms would prove very poorly adapted to life in the wild and might perish entirely.

If, however, the competition did not prove too severe, a few individuals might survive, and, from this start, nature would then gradually erase the effects of man's selection and substitute those of her own.

The contrast between Lamarck's theory and Darwin's should be quite evident. There is likewise a contrast with respect to the recommendations for human conduct. In this respect, the recommendation that is provided by Darwin's theory is a more "dangerous" and perhaps a more distasteful one, but if it represents the truth, we should not hesitate to accept it. According to Darwin, there must exist in any human population some individuals that are better adapted to their environment than are others. If then the human race is to improve in future generations it is these individuals that should be the most successful in reproducing their kind. How can this be brought about?

In the first place, some agreement should be reached as to what constitutes the most perfect adaptation to the human environment. It is very doubtful whether we should ever be able to reach anything like a perfect agreement on this matter, but a certain amount of agreement could surely be attained, and even that would provide a basis for considerable progress. Again, it is reasonable to expect that perfect adaptation under certain social conditions (human environment) might be imperfect adaptation under others; but here, too, it should be possible to visualize certain common features in the adaptation to practically all human conditions, and this much would provide a safe basis for procedure. The authors of the present text will not attempt anything like an exact analysis of what constitutes perfect adaptation to human environment, for that is a stupendous problem which the great thinkers of all ages have attacked directly or indirectly. All that we attempt to do is to focus the attention of the reader on

the problem, so that he himself may do more effective thinking along these lines.

It is quite apparent that where mankind lives in the savage state features of adaptation are markedly different from those that would hold for a civilized community. In the savage a premium would be put upon brute strength, while in civilized man the premium would be put upon intellect. But the problem is a great deal more complicated than that. We might go on to say that the perfectly adapted man under conditions of modern civilization is not only intelligent, but is healthy, energetic, industrious, cooperative, and endowed with a sense of justice. Surely it should be one of our big aims for the future to achieve a society in which as many as possible of the men and women are endowed with these traits.

But how is this to be achieved? If we take our recommendation from Darwin's theory, it amounts to this. The men and women with these fine traits should be more successful in reproducing their kind than are the others. To a certain extent this matter takes care of itself, and under many conditions an inevitable progress is made. It seems inevitable that in general the men and women who are unintelligent, unhealthy, sluggish, lazy, blindly selfish, and unfair will make a failure of life and will be less successful in reproducing their kind than are those with the opposite traits.

Under certain conditions, however, this plan of things is seriously impaired. During war it is likely that the best blood is killed off. In any vicious aristocracy, either political or economic, the most desirable types of men and women are often not allowed to survive and reproduce. Without going into the matter any further at this point, we can at least be safe in concluding that when society is conducted so as to give all individuals a fair opportunity to express those desirable traits with which they may be endowed, the

greatest progress in human selection will result. Let competition continue, but let that competition be as fair as possible, lest the benefits be impaired and the results seriously distorted.

It should be clear that there is nothing brutal contemplated in this program. Nothing could be more unwise than actively to enforce the code of "survival of the fittest," and ruthlessly to eliminate all that fall below some rigid artificial standard of perfection. Quite the opposite methods are called for in the proper application of Darwinian principles to man. Every man must be given a fair opportunity to express his capacities, and the stress is to be laid, not upon elimination of the unfit, but upon preservation of the fit.

This theory of Darwin's took the scientific world by storm, and was rather generally accepted during the four decades following its publication. Not only in biology but in many other lines of human thought as well it exerted a profound influence. Naturally there were many objections raised to the theory. Two of these objections will be worth while considering at this point.

In the first place, it was pointed out that there are two general types of evolutionary changes that must be accounted for: quantitative changes, or mere changes in the degree of development of certain existing structures; and qualitative changes, or radical changes in type, involving the production of brand-new structures. It was admitted that the natural selection theory could explain the quantitative changes, but it was claimed that this theory could not explain the qualitative changes.

In the example that was considered, the difference between the giraffe and its horse-like ancestor was quantitative. It was a difference in the length of neck and fore-limbs, that is, a mere difference in the degree of development of structures possessed by both types

of animal. Natural selection explained this change, but the explanation depended upon the fact that there was some variation in the horse-like ancestor to begin with, a few of the animals being slightly taller than the rest. If, in the ancestral form, there had been no such variation in the direction of greater height, if, in other words, every one of the horse-like ancestors had been exactly six feet high, natural selection would never have been able even to make a start toward the production of the giraffe.

Consider now what is involved in a qualitative change. A certain ancestral organism has no hair whatsoever. One of the types which has descended from this ancestor possesses hair. How can natural selection explain this evolutionary change? It would, of course, be easy enough to explain how a long-haired form had been developed from a short-haired ancestor, for this would be merely a quantitative change in existing structures. But if the ancestor has no hair whatsoever, and the descendant possesses hair, this involves a qualitative change, the production of a brand-new structure which did not exist before. In such a case natural selection cannot even make a start. It was concluded, therefore, that, although the natural selection theory might explain quantitative evolutionary changes, it failed to explain the many qualitative evolutionary changes that must have taken place in the past.

This first objection would merely limit the scope of the natural selection theory; the second objection was more serious. It was claimed that in actual practice the gradual cumulative gains brought about by selection always reached a definite stopping point beyond which further gain was impossible. It was felt that this stopping point was the species boundary, so that although natural selection might pull the species up to its maximum development with respect to any char-

acter, it would never be successful in taking that final critical step into the next species. For example, natural selection might change the horse-like ancestors of the giraffe from six feet in height up to seven feet, but no further gain could be made. The seven-foot animals would have among their progeny none that were any taller than seven feet, so that it would be impossible for natural selection to carry the gain in height any further than this. In this case then, natural selection would serve to produce a rather tall variety of horse, but it would be unsuccessful in producing the giraffe. This objection was based in part upon actual experiments that had been performed, in which it was found that there was this definite limit to the gains that could be made by selection.

Although Darwin's theory was successful in overcoming the objections that had been raised to Lamarck's theory, there still remained, therefore, two critical objections that had not been overcome. We shall see whether any subsequent theory was successful in escaping these two objections, (1) that only quantitative changes could be accounted for, and not qualitative, (2) and that the gradual progress that was made by selection was not successful in taking the critical step from one species to the next, that is, could not cross the species boundary. It should be pointed out that these two objections in no wise serve to prove that a struggle for existence and natural selection do not actually take place. These phenomena are recognized as established facts. It merely becomes doubtful whether these forces can account for all the evolution that has taken place in the past without the assistance of still other critical forces that Darwin had failed to recognize. The reader should further be reminded that this doubt that was cast upon Darwinism was directed merely at the adequacy of Darwin's explanation of evolution, and not at the fact of evolution itself.

V

THE MUTATION THEORY OF DE VRIES

The explanation of evolution proposed by De Vries introduced the modern period in the study of evolution. The preceding period, which may be called the mediæval period, culminated in the work of Darwin. During that period, the method used was observation and inference. Darwin carried this method to the limit of its possibilities, both in space and time, making observations throughout the world, and studying rational conclusions for more than twenty years before publication. Inference from observations, however, is not demonstration. Any further progress in the study of evolution demanded a new method, and this was introduced by De Vries. It is the method of experimentation. Instead of observing the resemblances and differences of plants, for example, and inferring relationship, plants were made to reproduce under control to see whether new species are actually produced. If by this method a new species is observed to come from an old one, the result is not an inference, but a demonstration.

Hugo De Vries was born at Haarlem, Holland, in 1848, and is still actively at work with his investigations. He studied at the universities of Leyden, Heidelberg, and Wurzburg, receiving the best training in biological technique that was possible at that time. He became professor of plant anatomy and physiology at the University of Amsterdam, and published the results of some important investigations on the structure of plant cells.

His call to the subject of evolution came in an unexpected way. He was botanizing in an area in Hol-

land where native vegetation was still present. Among the plants he was observing, he discovered an introduced plant growing abundantly, a primrose, afterwards found to be a native of the United States. As he examined these immigrant primroses, he found an individual here and there very different from the majority, but still a primrose. He began to suspect that these occasional individuals might have come from the ordinary forms; if so, here was one species producing another one.

He took specimens of the primrose to his Botanical Garden and began a series of experiments, to see whether the common form occasionally produced an entirely different one. The method used is known as pedigree culture, the pedigrees of the different individuals being carefully recorded. This was continued for thirteen years, and by that time De Vries had the exact records of the pedigree of every primrose in his garden, running back through many generations. As a result, he found that now and then an entirely new kind of individual would suddenly appear in a pedigree. Upon the basis of this work, De Vries announced the theory of "mutation" as an explanation of evolution.

The explanation of evolution which is offered by De Vries is very similar to that of Darwin's. In fact there is really only one feature in which the two theories differ, but that feature is of critical importance. The importance of this difference may be realized when we recall the objections that were raised to Darwin's theory, and notice how De Vries, by making this one critical change in the theory, was successful in overcoming these objections.

In criticism of Darwin's theory, it was urged that: (1) although quantitative changes, or changes in the degree of development of some preexisting organ or character, might be brought about by natural selection

in the way that Darwin had outlined, evidently a great part of the evolution that has taken place in the past must have consisted of qualitative changes, or the actual appearance of certain new organs and characters where nothing of the sort had existed before; and Darwin's theory seemed quite inadequate as an explanation of changes of this latter sort; (2) experience in breeding has strongly suggested that, although selection may be effective in the gradual accumulation of the effects of small variations up to a certain point, this critical point, the species boundary, can never be passed, so that it is really impossible to produce a new species from an old one. These were two important objections to the Darwinian theory; it is interesting to see how De Vries is successful in escaping these objections.

De Vries recognizes the truth in Darwin's statement that there are never any two individuals that are absolutely alike. He acknowledges that these small individual variations always occur; but he maintains that it is not the little variations of this sort that are important in providing a basis for explaining evolution. In addition to these small, quantitative variations that are always taking place, De Vries points out that there will occasionally occur variations of quite a different sort. Occasionally there will appear in a population of animals or plants one or a few individuals which are quite different from all the rest. They differ not merely in having some organ or character slightly more or slightly less developed, but in possessing some character that the others lack, or in lacking some character that the others possess. De Vries presented considerable evidence to prove that radical variations of this sort occasionally take place, and other investigators have also observed many instances of this phenomenon. For example, in a population of fruit flies which normally have red eyes there

may suddenly appear one individual which has absolutely white eyes; in a group of corn plants of normal size there may appear a few individuals that are absolute dwarfs, being less than a foot in height even when grown in rich soil; a herd of normal cattle may possess one animal which is without horns; in a field of American evening primroses there may appear a few plants that are giants, having a much greater size in all of their parts than the other plants. It can be seen at once that these variations are of quite a different sort from the small, quantitative, individual differences that Darwin used in his theory.

These conspicuous, qualitative variations are called *mutations,* and, according to De Vries, it is mutations which lie at the basis of evolution. Otherwise his theory agrees entirely with Darwin's. De Vries also believes that natural selection operates to bring about a survival of the fittest, with an elimination of the unfit. The one difference between the two theories is that Darwin used the small, quantitative, individual variations which are constantly occurring, while De Vries uses the abrupt, qualitative variations which appear only occasionally. This one fundamental difference between the theories, however, carries with it many important consequences.

According to De Vries, there occurs the same competition or struggle for existence, and natural selection comes into play to bring about the survival of the fittest, just as in Darwin's theory; but the natural selection (so far as it is effective in bringing about evolution) takes place among the mutations rather than among the small, quantitative variations. As Darwin pictures it, natural selection, by leading along the small quantitative variations in a given direction, and gradually accumulating these effects, finally, after the lapse of a great many generations, results in enough change to produce a new species. De Vries,

on the other hand, maintains that new species will occasionally appear very suddenly and spontaneously (the cause being unknown) in the form of mutations, and that natural selection will merely decide which of these mutations is fit to survive.

In this connection a word should be said as to the occurrence of mutations and the possible fate which awaits them. A given species of plant or animal may go along for a number of generations without showing any mutations at all (merely showing the small, quantitative variations of the Darwinian type, which, according to De Vries, will lead to no real evolutionary results). Then, among the progeny of one generation, there may suddenly appear one or a few individuals which are the result of mutation, and which differ radically from all the others. After that the species may again continue for a number of generations without having any mutations, but sooner or later it will again produce among its normal progeny a small group of mutated forms. So it is that, although mutations are infrequent, in the course of enough generations a given species may show quite a number of them.

There is never any way of knowing when the next mutation may take place or what it may amount to. The change may affect any part of the organism, and may modify that part in almost any conceivable way. Furthermore, it should be realized clearly that the changes produced by mutation are not necessarily adaptive; that is, they do not necessarily serve to provide the plant or animal with any better equipment for coping with its environment. The changes are fortuitous, a matter of chance. Some may *happen* to be useful, but others may be useless or even harmful. In this respect, mutations are similar to the small, quantitative variations of Darwin. If the change produced by mutation happens to be useful, if it serves to adapt the plant or animal to its environment better than

before, then the mutants (individual plants or animals produced by mutation) will have an advantage over the others in the struggle for existence, and will be likely to survive while the others perish. If the change is useless, if it neither helps nor hinders the organism in any appreciable way, the mutants will have no advantage over the others, and whether or not they survive will be decided by chance. If the change is actually harmful, being a distinct disadvantage to the organism in its attempt to adjust itself to environmental conditions, then the mutants will be at a disadvantage in the struggle for existence, and will perish while others survive.

De Vries believed, and presented evidence to support his belief, that mutations of these various types would occasionally take place in all species of plants and animals. Natural selection would then proceed to "judge" the mutants, and, if they were better adapted than their parents, they would survive, multiply themselves, and eventually crowd out the parental type. From the start, the mutants would be sufficiently different to be regarded as a new species. In this case, therefore, natural selection does not operate gradually to build up new species, but merely decides which, among the many new species spontaneously produced by mutation, are to survive and therefore be effective in bringing about evolution.

It should be rather apparent that this mutation theory of De Vries' escapes the two objections that were raised to Darwin's explanation of evolution. In the first place, the objection that only quantitative changes can be explained is not applicable here. Mutations involve qualitative changes, adding to the organism new characters that were not present before, or eliminating old characters. It should not be concluded that mutation is ineffective in bringing quantitative changes, for these also may occur.

In the second place, an objection that was raised to Darwin's theory was that the accumulation of the effects of the small, quantitative changes would never be effective in passing the species boundary. This objection cannot be applied to De Vries' theory. The mutations are really new species from the moment they appear. It is not at all the task of natural selection to bring about an accumulation of the effects of these changes, but merely to decide which of the many prospective new species shall survive and actually become established as a species in nature. It is evident, therefore, that the mutation theory of De Vries escapes the objections that were raised against the Darwinian theory.

It will be worth while again to emphasize this fact. Although the Darwinian explanation of evolution has thus become somewhat discredited and supplanted by what seems a more accurate theory, it should be remembered that what was really Darwin's main idea, the idea of natural selection, is still believed to be accurate. In fact it may safely be stated that (with a few exceptions, which will at best be only temporary), a competition or struggle for existence of one sort or another is bound to take place; and whenever this struggle for existence takes place, natural selection, through the survival of the fittest, will follow as a consequence just as inevitable as the law of gravitation.

If one seeks in De Vries' mutation theory a recommendation for human conduct, he finds one which is essentially the same as that provided by Darwin's theory, for the final evolutionary consequences are brought about by natural selection in each case. As before, we find that the evolutionary possibilities with respect to man are, to a great extent, in the hands of man himself. In this vast human population of ours we are forced to believe that there must be occurring from time to time a few mutations. What these mu-

tations will amount to can never be predicted. Many of the mutations will doubtless bring into existence individuals who are really more poorly adapted to their human environment than are most persons. What shall be done with these? If the abnormality or defect that is introduced by mutation is not a very serious one, then the prospect need not concern us deeply. If, for example, only some minor anatomical defect is produced, such as a condition where the individual has very short fingers and toes, we have no reason to worry very much about the situation. Short fingers and toes are, of course, clearly a defect. The individual possessing them is somewhat more poorly adapted to his environment, has a rather faulty equipment with which to cope with the demands of life, as compared with the mass of normal individuals that surrounds him. The defect, however, is really not serious, and there are in existence more than enough serious defects to occupy our concern.

If, however, the defect that is introduced by mutation is of a more serious character, a social danger at once confronts us; we are presented with an important problem which should be solved. If, for example, mutation should result in a mental defect which brought feeble-mindedness and serious criminalistic tendencies, the individual possessing these traits would be a burden and a menace to society. In such a case there is no necessity, and no real justice, in the punishment of this unfortunate individual with the death penalty; but it is clear that it should be made impossible for such an individual to reproduce and thus multiply the defect.

On the other hand, we must conclude that there will occasionally take place mutations which result in somewhat superior individuals. This superiority might be physical, such as greater strength, or resistance, or improved powers of coordination, or it might be

mental. Since the most desirable and promising prospect in human evolution lies in the improvement of mentality, it should be our particular concern to make the most of any mutations that tend in this direction. Individuals of superior mental capacity (provided this be not associated with any vicious tendencies) should be given a full opportunity to express their capacities, so that society in general shall enjoy the benefits thereof; and, above all, such individuals should be allowed and even encouraged to reproduce, so that their desirable traits will be multiplied in future generations.

Progress in human evolution along the general lines just indicated is certain to take place wherever the political, economic, and educational systems are sound. Either under an intelligent democracy or a benevolent autocracy superior individuals have the right of opportunity for self-expression and propagation. The right economic situation is one which makes it readily possible for any really capable individual to attain a comfortable though not extravagant and luxurious standard of living. The right educational system is one that puts a higher education within the reach of every individual who gives good evidence of his ability. One is comforted and encouraged by the thought that in these matters the world as a whole is much better off today than ever before (save for a few distressing local situations which should be speedily improved). There is always room, however, for improvement in the details of the political, economic, and educational systems, and there will always be ample benefits received from such improvements through the proper direction of human evolution.

The mutation theory of De Vries is the third and last of the "classic" explanations of evolution. This is the theory that was rather generally accepted by biologists at the beginning of the twentieth century. The exact present status of this and the other theories will be discussed in a later chapter.

VI

SOME OTHER THEORIES OF EVOLUTION

The theories of Lamarck, Darwin, and De Vries may be regarded as the three "classic" explanations of evolution. Each one was, at the time of its presentation, more satisfactory in fitting the known facts than any other contemporary explanation; each one provided what was presumably a thoroughgoing interpretation of all the evolutionary events that had taken place in the past. It is these three explanations, therefore, that have during the past century exerted the greatest influence on biological thought.

It has been seen how Lamarck's theory was rather supplanted by Darwin's because the latter was successful in avoiding certain critical objections that had been raised against the former. In a similar way Darwin's theory was supplanted by that of De Vries. It should be understood, however, that when we speak of one theory "supplanting" another, we mean nothing further than this, that it is accepted by the majority of those biologists who are in the best position to pass critical judgment. It is not true that scientists were unanimous in discarding Lamarck's theory at the time that Darwin's was published; quite a number maintained very stoutly their belief in Lamarckism in spite of the seemingly fatal objections that were raised against it. Likewise there are some who today maintain that Darwin's theory is a more satisfactory explanation of evolution than is that of De Vries. These differences of opinion among biologists are to be ac-

counted for by the fact that some, in the course of their own investigations, encounter repeated and impressive instances of one type of evidence only, while others are encountering another type of evidence. Since conclusions are reached through a critical weighing of different types of evidence, it is not surprising that there should be some difference of opinion on such matters. We are rather safe in stating, however, that during the last two decades the mutation theory of De Vries has been the one favored by a majority of the authorities.

In addition to these three "classic" theories, there have been proposed numerous other explanations of the evolutionary process. Most of these others have proved worthless, either because they were based upon wild speculation without adequate foundation in fact, or because they contained some obvious fallacy. There are three of these others, however, that are worthy of mention. None of them is quite satisfactory as a complete explanation of evolution, but each contains points which have a real bearing upon the problems of evolution. All of them were proposed during the latter part of the nineteenth century.

ORTHOGENESIS THEORY

Practically all biologists recognize that there must have occurred from time to time "determinate" variations, variations along apparently predetermined lines. Some unknown internal force causes a plant or animal to change in a certain way. Generations later, among the progeny of this individual there will take place a further change in the same direction, and later even more changes will take place along this same "predetermined" line. These changes are in no way (so far as we can see) determined by the effects of natural selection or any environmental influence, but seem to be regulated entirely by some unknown power that is

internal in the organism. This rather mysterious phenomenon is referred to as "orthogenesis."

Most of the evidence for orthogenesis is provided by the geological record. If we examine the fossil forms of some group of plants or animals that lived during a certain geologic age, and then compare these forms with the representatives of that same general group that appeared in preceding and succeeding geologic ages, we are likely to find clear indications of orthogenesis. We see that a characteristic change has taken place between the organism of one age and those of the next, and that in the succeeding ages there has taken place a series of further changes along this same predetermined line. Since we cannot see how environmental influences could have brought about this peculiar succession, we are inclined to attribute it to some unexplained force that is inherent in the organism. For example, in our primitive plants there appears a certain structure that is 16 units in length. Another group of plants, somewhat more modern than the first, contains the same structure with a length of 8 units. As we pass to the more and more modern groups of plants we find this structure gradually being reduced, the changes passing through the series 4, 2, 1, ½, 0 units. Since this particular structure in plants is rather removed from environmental influences and outside the scope of natural selection (so far as we can see), it is strongly suggested that some internal force has been driving along continuously in the same direction.

Some evidence of orthogenesis is also provided by breeding experiments with modern plants. The Boston fern suddenly produced a type that was a dwarf. Some time later these dwarf descendants produced a type that was still more of a dwarf. Again, the singly compound leaf of this fern was supplanted in some of the descendants by a doubly compound leaf, and later

changes in this same line achieved a triply compound, and finally a quadruply compound leaf. These changes, which are evidently along a predetermined line, are attributed to orthogenesis. It is implied that there is in existence an internal force that operates independently of environmental influence.

Orthogenesis has been advanced by some as an explanation of evolution. All evolutionary changes could be accounted for by saying that they were due to the operation of this mysterious, internal, directing force, which had been playing its rôle through the ages quite independently of outside influence. Although this might be a simple account of evolution, it could not be regarded as an explanation. In order to explain the process, it would be necessary to understand this mysterious internal force and to see why and how it operates. In truth, orthogenesis explains nothing, but merely directs our attention to one of the phenomena of evolution that requires explanation.

ISOLATION THEORY

If a given race of men remains, through the centuries, living in some rather restricted locality, the form of language used by all the individuals of that race will be essentially the same. If, on the other hand, certain members of this race migrate to a new territory, and remain there for a few centuries without holding any intercourse with their relatives at home, at the end of that time the form of language of the colonists will differ in many of its characteristics from that of the stay-at-homes. This result has been brought about by the fact that the colonists have been isolated from the rest of the race.

Many of the features of evolution can be accounted for by exactly these same principles. If a given race of animals remains, through the centuries, living in some rather restricted locality, the characteristics of

all the individuals of that race will be essentially the same. At one time or other there may have appeared in this race a few individuals which, due to some type of variation, were distinctly different from the rest. Now if this difference were of no significance in the struggle for existence it would gradually be erased. The individuals which possessed the modification would mate with normal, unmodified individuals. The progeny would, in general, show characteristics intermediate between those of the two parents. As a result, the modification would be reduced one-half. These "half-modified" forms would in turn mate with certain of the normal, unmodified individuals which make up the great bulk of the population. The progeny from such matings would then be one-quarter modified. Thus the original modification would gradually be erased or "swamped out" through the free crossing of the few modified individuals with a series of those unmodified forms which go to make up the bulk of the population. This free intercrossing tends to maintain a general average, to keep the characteristics of every individual of the race very much the same. This is the result which obtains when all of the individuals of one race of animals are freely intermingling in one region.

If, however, a few of the animals of this race migrate to a new region, a region which is (or becomes) separated from the original one by some geographic barrier (for example, mountains, bodies of water, stretches of desert), such that any return migration is rendered difficult, important consequences will follow. In this small group of colonists there may appear a few modified individuals. Under the circumstances, these individuals will have a very limited choice in mating. Since the group of colonists is so small, it may be that there are about as many modified as unmodified animals. Hence the result of free crossing within this

small group will finally produce a population of "half-modified" individuals. The population of colonists is now somewhat different from the original race, and this is only the start. The original change will open the way to further changes. At the end of some centuries the colonists will be different in a good many respects from the stay-at-homes. Thus isolation brings evolutionary changes in the characteristics of animals (and plants) in much the same way that it brings changes in language.

This is not mere speculation. There is in existence a great mass of evidence to support these ideas. We find that where free crossing is possible among all the individuals of a race of animals these individuals are essentially the same in all of their characteristics. We find that where a small group has become isolated some centuries back there are characteristic differences between the members of this group and the parental race. If the isolation took place at an earlier date, the differences are greater. A great many of the differences that we see among our plants and animals of today have come through the effects of isolation.

But is this a satisfactory explanation of evolution? It may serve to explain the establishment of differences between certain groups of animals and plants, but evolution amounts to something more than this. The true, fundamental feature of evolution lies in the progressive changes that have taken place, those changes which make the plants and animals of today better adapted to their environment than were their more primitive ancestors. This feature, the true progressive evolution, is not explained by the isolation theory. Isolation accounts for the establishment of mere differences, but not for the progressive evolutionary changes.

Consequently, although most biologists recognize the truth of the isolation theory, they do not regard it

as a satisfactory explanation of evolution by itself. This theory, however, provides a very useful corrollary to the theories of Lamarck, Darwin, or De Vries. Choose one of these "classic" theories to explain progressive or adaptive evolution, the production of the more advanced organisms from the more primitive, and then let the isolation theory explain "lateral" evolution, the multiplication of species "on the same level."

HYBRIDIZATION THEORY

When we speak of a "species" of plants or animals we refer to a group within which the individuals are alike with respect to their more important characteristics; but very commonly a species may be composed of several smaller groups known as "varieties." One variety differs from another with respect to characters of minor importance.

In the normal course of events, an individual of any given variety will mate with another individual of that same variety; but by artificial means man can mate an individual of one variety with an individual of another variety. A mating of this sort is called a "cross," and the progeny which result from such a mating are "hybrids" (half-breeds). In view of the fact that the two parents in a cross differ from one another with respect to some of their characteristics, what will be the nature of the hybrid progeny that result? In general it may be answered that the hybrids will exhibit one or more of the following three features. (1) Hybrids may be intermediate between the two parents. For example, if one parent has red flowers and the other parent has white, the hybrid may have pink flowers. (2) Hybrids may possess some of the characteristics of one parent and some of the characteristics of the other, thus exhibiting a new combination of characteristics. For example, one parent might be tall and have smooth

leaves; the other parent might be short and have hairy leaves; and the hybrids might then be tall and have hairy leaves. (3) Very rarely hybrids may exhibit characteristics that are possessed by neither of the parents. For example, the two parents might both have white flowers (differing, of course, in other respects) and the hybrids purple flowers, the purple being a new character that has evidently been produced by the cross. Of course the peculiarities of hybrids could be described in a great deal more detail than this, but at present we are interested in noting merely this one very significant fact: whether the hybrids show an intermediate grade of character, or a new combination of characters, or some new character, in any of these cases the hybrids are really a new type of organism, a new variety that had not existed before the cross was made. Any method of producing new varieties has (presumably) considerable evolutionary significance, for this may well lead to the production of new species, and eventually to still greater evolutionary changes.

Before deciding whether this phenomenon has any great evolutionary significance, however, it will first be necessary to seek the answers to two important questions. (1) We know that hybrids may be produced artificially by man, but will they be produced without man's agency among plants and animals growing in the natural state? Roughly speaking, this may be answered in the affirmative; there is excellent evidence that crossing takes place freely among many of the plant varieties growing in nature, and this is probably true, to a more limited extent, for animals as well. (2) Once the hybrids have been produced, will their progeny continue to show the same new traits that characterized the hybrids themselves? In general, hybrids produce among their progeny three different types of individuals: some like one of the original

grandparents that entered into the cross; some like the other grandparent; and some just like the hybrids themselves. Some of the members of this last group will thereafter breed true, producing progeny all of which are like themselves; so we may be assured that the new varieties produced by crossing (hybridization) will tend to perpetuate themselves.

It becomes evident, therefore, that hybridization must have considerable significance in evolution. If we consider the matter a little more carefully, however, we realize that the rôle of hybridization is subsidiary to, or contributory to natural selection. As we have seen, hybridization produces new varieties that would not have appeared otherwise. These new varieties are then subjected to natural selection. If they prove to be more poorly adapted to their environment than are the other individuals of that species, the hybrids will be at a disadvantage in the struggle for existence and will soon be exterminated. If, however, they prove better adapted than the others, they will survive and may even crowd out and supplant the ancestral varieties. Evidently the rôle of hybridization is to produce a greater number of varieties from which nature can make her choice. This is really a very important function. Obviously the greater the number of varieties produced, the more often will there appear a new variety which is better adapted, and will therefore provide a basis for evolutionary progress. Hence hybridization serves to "speed up" evolution, making it possible for progressive evolution to take place at a more rapid rate than otherwise.

In this connection we may note an interesting and important fact that very few people realize. What is the real function of sex? Most people would answer that this function is reproduction; but this is really not true, as biologists can readily see. Sex is not the only method of reproduction employed by plants and

animals, but only one of several. Furthermore, of the several methods of reproduction, sex is distinctly the poorest, the least efficient. Other methods of reproduction possess all of the advantages and none of the disadvantages of the sex method. Since this is true, why is sex the established method of reproduction in our higher animals and plants? Out of a number of possible methods of reproduction, why should nature have chosen the very poorest with which to endow her best plants and animals? Evidently sex brings some great advantage which is more than enough to offset the disadvantages inherent in this method. Sex is relatively poor as a method of reproduction, but it secures a great advantage in connection with reproduction, an advantage not possessed by any of the other methods. This great advantage is the one which we have just seen. Sexual reproduction produces a greater number of varieties than does any other method of reproduction. Thus, by providing nature with a greater range of choice, sex makes evolution take place faster than otherwise. We may conclude, therefore, that the reason that sex is the established method of reproduction in our higher animals and plants is not because it is the best method of reproduction, but because it brings a great advantage for the process of evolution. It might well be said that the very existence of sex is good evidence of the fact of evolution.

Some have claimed that hybridization, considered in connection with natural selection, provides a complete explanation of evolution. This extreme view is not justified. In the first place, hybridization can occur only in plants and animals that have sex. Since our most primitive plants and animals do not have sex, evolution must have been accomplished in these early groups by some other means. In the second place, although hybridization appears to produce new varieties, it is really not the final cause that underlies this

production. To put the matter in another way, hybridization can produce new varieties only after certain other evolutionary forces have already operated. This point comes out clearly when we attempt to visualize why it is that hybridization produces new varieties. If two individuals of the same variety are mated, no new varieties result. Why not? Because the two parents were similar. If individuals of two different varieties are mated, new varieties result. Why? Because the two parents were different.[1] We may conclude, therefore, that hybridization produces new varieties only because the parents to the cross are themselves different. How did the parents come to be different? Again it might be said that this existing difference is to be accounted for by some previous hybridizing; but this is merely begging the question. Originally the differences must have been caused by some means other than hybridization. These are two good reasons why hybridization does not provide by itself a completely satisfactory explanation of evolution. Even so, hybridization must be regarded as having considerable importance in evolution, for in many groups of animals and plants hybridization makes evolution take place much faster than otherwise; and furthermore, hybridization may often secure a very desirable combination of characters that would be very unlikely to be brought together by any other means.

We may now conclude that none of these three "other" theories is in itself a completely satisfactory explanation of evolution. It is equally clear, however, that each contains forces which are contributory to

[1] Even in the case where the hybrids exhibit a character not possessed by either parent, this has been brought to pass by a combination of certain "invisible" elements from one parent with other invisible elements from the other parent. This fact can be proved very neatly by the proper experimental breeding.

evolution. To get comprehensive ideas on the possible explanations of evolution one should, therefore, have some understanding of orthogenesis, isolation, and hybridization, as well as the classic theories of Lamarck, Darwin, and De Vries.

Since none of the three theories that we have just been considering is a complete explanation of evolution, we could hardly expect them to provide any very complete recommendations on the matter of human evolution. A few ideas, however, might be suggested.

Since orthogenesis is so little understood, since it operates at best in a rather limited way and effects evolutionary progress very slowly, it would probably be difficult even to visualize this phenomenon in human evolution. If orthogenetic changes actually are taking place to any considerable extent in man, the same methods that one would employ to preserve the benefits of mutation would be the safe course to pursue here also. If those individuals that show orthogenetic change in the right direction are provided with the proper opportunities, they will perpetuate not only this desirable change, but also the capacity for further desirable changes in the same direction. Individuals showing dangerously bad orthogenetic changes should, of course, not be allowed to reproduce.

Isolation, which in itself accounts merely for the establishment of differences between varieties and species, and does not account for progressive evolution, provides no good recommendation on controlled human evolution. In the past, isolation has undoubtedly been very important in bringing about the differences which we see today between the various races of mankind. For the future, however, we are not desirous of developing further racial differences of this sort. In fact, it is our aim to maintain the present human races without any further splitting up, but to effect

improvement within each of them through control of progressive human evolution.

Hybridization might seem to recommend for man the crossing of different varieties, for in that way desirable new varieties are sometimes brought into existence. To jump at this conclusion would, however, be exceedingly dangerous. It is true that crossing varieties may sometimes result in superior individuals, through combination of the desirable traits of both parents. It should be remembered, though, that crossing may also produce inferior individuals, through combination of the undesirable traits of both parents. Since it is (as yet) rather hopeless to predict with certainty which of these results might be obtained in any given case, human hybridization is a rather hazardous practice. On the basis of actual breeding experiments with plants and animals, and also upon inferences that may be drawn from the results of past human breeding, the following general recommendation is fairly well warranted. Wide human crosses (beyond the color line) are not advised, for the results which these are likely to bring in the long run are more often unfortunate than fortunate. Less wide human crosses (between slightly different races within the color line) can for the most part be recommended, for they evidently bring more advantages than disadvantages.

VII

MODERN VIEWS ON EVOLUTION

THE reader is now able to distinguish six theories that have been advanced in explanation of evolution, and knows something of the merits and demerits of each. It has been indicated that the orthogenesis, isolation, and hybridization theories, although containing features of undoubted significance, definitely fall short of being complete or thoroughgoing explanations of the whole evolutionary process. Lamarck's theory of Use and Disuse might well have been accepted as a thoroughgoing explanation of evolution, save for the fact that it rested upon inheritance of acquired characters, an assumption which clearly was not supported by the known facts. Darwin's Natural Selection at first seemed an even more attractive and reasonable explanation, but here also the theory was not supported by certain critical facts, for experimental breeding rather clearly indicated that selection was never effective in passing the species boundary. These considerations have, of course, left the impression that the most acceptable of all the proposed explanations is the Mutation Theory of De Vries.

This, we believe, is a fair representation of the consensus of opinion among biologists at the opening of the twentieth century; but we must hasten to add to this statement two very important reservations. First, it is distinctly not true that all biologists at that time held this same opinion as to the relative merits of the several theories. Second, even those who did have

these general views were in no position to maintain that their views were supported by absolute proof. In short, although the mutation theory seemed the most likely of all explanations that had been presented, there was no absolute assurance that it was the true or final explanation of evolution, and so scientific men attempted to maintain an open mind on these matters, and stood ready to change their opinion in response to any new and critical evidence that might be forthcoming.

When we think over these various theories with the hope of arriving at some definite decision as to the real explanation of evolution, the main impression that we are likely to get is one of uncertainty. The matter is by no means settled. Perhaps we may prefer one theory to the others, but, lest we be guilty of jumping to a conclusion with too much haste, let us consider three propositions which have an important bearing in this connection.

1. After all, is the "problem of evolution" a single problem? Is it not instead a complex of numerous smaller problems? Surely this latter is the case, for we are obliged to explain many different things, to answer many questions, before we can account for all the results of evolution that we see in nature today. Any explanation of evolution must be based on some change or variation that appears in an individual organism, something which makes it different from the other individuals of the same species. Unless we have such a change to begin with, it is impossible to devise any scheme to explain evolution. So the first question to be answered is, "What is the cause of variation?" Next we face the possibility that variations of more than one type may be taking place. Consequently, for any complete understanding of evolution, we must distinguish the different types of variation that are taking place, and decide which of

the known types is significant in providing a basis for evolution. Following this, we should understand how the variations are perpetuated, multiplied, and manipulated by nature to bring about evolutionary progress. Since all of these questions should be answered before any complete understanding of the evolutionary machinery is possible, we must conclude that the evolution problem is really a complex of numerous problems. We could hardly expect that any single idea would itself provide a solution for all these problems.

2. Is it necessary that we subscribe to a belief in any one of the theories, to the complete exclusion of the others? Is it not quite possible that every one of them may be a factor in evolution, and altogether probable that no one of them by itself can adequately account for all the features of evolution? This suggestion is consistent with the preceding one. If evolution is really a complex of several distinct problems, it is quite likely that one theory may provide the best solution for one of the evolution problems, while other theories provide better solutions for the other problems. Furthermore, it is certainly not true that any one of the theories is absolutely contradictory of the others. It is conceivable that the evolutionary forces which Lamarck describes might be at play side by side with those of Darwin and De Vries; and at the same time orthogenesis, isolation, and hybridization might also be in operation to contribute to the general results. Since this is conceivable, may it not be the actual truth? May it not be quite true that each and every one of the theories serves to explain some part of evolution, while no one of them can explain all of evolution?

3. After all, can we make much real progress toward deciding upon the relative merits of the different theories until we have in our possession more of the critical facts? In our discussion of the theories we are

always coming face to face with questions of fact, running into some disputed or doubtful point about which we might argue indefinitely and to no purpose; for such disputed points cannot be settled until we know the true facts which bear upon these points. A theory is convincing only when it is demonstrated that the assumptions which it contains are consistent with the facts of nature. Hence the only sensible way to settle discussions on evolutionary theories is to renew our investigation of nature, and seek from her the answers to our questions. This was exactly the conclusion that scientific men arrived at, and, with the opening of the twentieth century, they abandoned (in good part) their rather fruitless discussions, and proceeded to devote their energies toward discovering more of the critical facts.

At that time there was introduced (mainly by the work of De Vries) a new and improved method of discovering facts. Previously men had merely observed natural phenomena as carefully and extensively as possible and had drawn inferences from these observations. They had seen innumerable evidences of evolution, and had then inferred that the results which they saw had been brought about in certain ways. They were sure that evolution had brought about these results, but it was a matter of inference as to how evolution had operated in bringing about these results. Then, with the opening of the twentieth century, a method of investigation was introduced which made it possible not only to observe the results of evolution, but actually to observe nature in the act of bringing about these evolutionary results.

This method of investigation was the experimental method. Plants and animals were grown under observation for many generations, and were mated artificially according to the plan of the investigation. The hope was that a certain amount of evolutionary change

would take place under the eyes of the investigator. It was felt that if one could in this way "catch evolution in the act," he could come much closer than otherwise to understanding the methods of evolution.

In this way the more general study of evolution gave birth to and became diverted into the experimental study of heredity, the science of "genetics." Almost immediately it became apparent that this new science was destined to play a large part in biology. An enormous amount of research was started in this field, and the results obtained were very gratifying. As a consequence, the last two decades have witnessed a series of rapid strides in the progress of our understanding of the principles of heredity. This progress has been of the utmost significance, not only in its bearing upon the purely theoretical aspects of biology, but also in a very practical way, through the improvement it has effected in methods of breeding our cultivated plants and domesticated animals. In fact, the experimental study of heredity has become more profitable than the more general consideration of the problem of evolution ever was. It is not surprising, therefore, that genetics, which was started merely as a means of solving some of the problems of evolution, has since come to be pursued for its own sake; so that today biologists are really devoting more of their attention to genetics than to evolution.

In the present volume, however, we shall not undertake a consideration of the fascinating science of genetics, for our interest here is in the more general problems of evolution. Here our interest in genetics goes no further than the light which it may cast upon evolution. Without attempting to go into details, therefore, let us see what answers may be provided by the science of genetics for some of the questions of evolution.

First, to consider the case of orthogenesis. Geneti-

cists have encountered, in their experimental breeding, certain cases which might be interpreted as evidence of orthogenesis. There are so few of these cases, however, as to indicate that changes of the orthogenetic type are the exception rather than the rule. Furthermore, even though geneticists may acknowledge the possibility that orthogenesis has played a real part in the evolution of the past, they deny the implication that this is due to some special internal force that has the peculiar function of directing evolutionary changes along predetermined lines. Instead they have concluded that orthogenesis is merely one of the manifestations of the same set of forces that also operate to bring about such other results as mutation.

As for isolation, the results of experimental breeding confirm the idea that this has been very important in establishing many of the differences that exist between the varieties and species of today. One trained in genetics can visualize, in much more exact terms than before, just how the results of isolation have been brought about. On the other hand, it can just as clearly be seen that isolation by itself can never bring about progressive or adaptive evolution. For these latter results other explanations are required.

Hybridization is, of course, much better understood than before. The geneticist can see in a very exact way how the crossing of different varieties results in a hybrid which may well be said to constitute a new variety. He can also see how very often the hybrids are superior to their parental varieties. Such new varieties may then become established in nature. Hybridization, therefore, can explain not only the mere multiplication of varieties, but also, within limits, real evolutionary progress. On the other hand, it is now possible to demonstrate very clearly that hybridization can produce new varieties only because the two parents in the cross are of a different constitution. And further,

it can be seen clearly that this difference between the two parents can itself be accounted for only by the operation of some force other than hybridization, that is, mutation. In short, hybridization is effective in bringing about evolution, only after a certain amount of mutation has already taken place.

It has been seen how Lamarck's theory of Use and Disuse, which required the inheritance of acquired characters as an essential part of the explanation of evolution, was discredited by the appearance of a mass of evidence which appeared to demonstrate that inheritance of acquired characters was impossible. For many years after that, and in fact until very recently, more and more evidence was gathered which still pointed in the same direction. Recently, however, some very reliable evidence has been presented which indicates that inheritance of acquired characters is really possible.

Without attempting to go into the details of this evidence, we may merely summarize the indications. In our very simplest plants and animals it would appear that a considerable amount of inheritance of acquired characters may be taking place, so that the Lamarckian scheme may well have played a large part in the evolution of these primitive organisms. In such cases, of course, there would be no "conscious effort" on the part of the organism, but this conscious effort was, after all, no essential part of Lamarck's theory. In our higher plants and animals, we have reason to believe that the inheritance of acquired characters can take place, at best, only under very special circumstances, circumstances which are capable of exerting a profound influence upon the organism without killing it. Such circumstances are not often realized. As to how important this may have been in evolution, we are very uncertain indeed, and the widest sort of difference of opinion exists. The best we can

do is to present this summarizing thought; namely, the Lamarckian scheme may have played a large part in the evolution of the more primitive organisms, a considerably smaller part in the evolution of the higher organisms. Certainly not all of the features of evolution can be accounted for in this way.

When we subject Darwin's theory of Natural Selection to a critical analysis in the light of our modern knowledge of heredity, we are forced to conclude that in one way Darwin was right and in another way he was wrong. In a very general sense, natural selection is the true and final explanation of progressive evolution; but if Darwin attempts to account for all evolution through natural selection among small quantitative variations, his theory is erroneous. Today we understand a great deal more exactly than Darwin ever did just what these small quantitative variations amount to. We recognize that selection may be successful in accumulating the effects of these variations, and we understand rather exactly how this result is attained. But we can also see plainly that such selection must always reach a limit beyond which further progress by the same means is clearly impossible, and we know that in every case in which selection has been tried this impassable limit is actually reached. To pass this critical limit requires that something new be introduced by mutation.

We finally fall back, therefore, upon the mutation theory. Mutation, although perhaps not in itself a thorough explanation of all the features of evolution, at the same time seems to be the phenomenon which underlies at least the great bulk of evolutionary change. Occasionally, among the individuals of a given variety, there may appear one or a few individuals which contain some new character, or lack some old one. If the change is an improvement, if the mutants are better adapted than were their ances-

tors, natural selection will operate to preserve the mutants and perpetuate them as a new variety (or new species, dependent upon the definition of "species"). If, however, the mutants are more poorly adapted than were their parents, natural selection will eliminate them. It is rather generally felt that this principle must underlie, directly or indirectly, the bulk of evolutionary change and progress that has taken place in the past.[1]

[1] It is true that, even in this mutation theory, some investigators see a serious difficulty. During the last two decades there have been discovered, and carefully studied, many hundreds of mutations in various plants and animals, and it is recognized that many of these are sufficiently different from the parent types to be called new species. It might well be expected that in the vast majority of these cases the mutant would be inferior to its parent. If the mutations take place absolutely at random (which is the case, so far as we can yet see) there is much greater chance that the change will be injurious to such a complicated bit of machinery as a living organism, than that it will effect an improvement. Hence we can readily believe that only rarely are improvements introduced by mutation. Even this, of course, would provide an adequate basis for progressive evolution. But if no mutation ever brought an improvement, this process would serve merely to increase the total number of species, and would not bring real progressive evolution. Therein lies the difficulty. Out of the many hundreds of mutations that have been seen to take place, there is (according to some investigators) not even one which can, beyond the shadow of a doubt, be recognized as a distinct improvement. This, of course, would be a serious difficulty, a great flaw in the mutation theory.

Most biologists, however, have great confidence in the mutation theory, holding the view that some of the mutations already encountered are real improvements, and will provide a basis for progressive evolution. Of course there is room for great differences of opinion on what constitutes an improvement. It might well be difficult for us to recognize such an improvement when we found it, for, although it is often easy to see how some of the existing characters serve to adapt the organism to its environment, it might be difficult to recognize the true merits of some entirely new character with which we had had no previous experience. As an example of this, if such an improvement should take place in man, would we immediately recognize as such the "superman" which resulted? After all, even though we might not be able to convince skeptics that any of the new mutations are improvements, investigation has at least revealed this much: today there exist

What causes mutation? We do not know, but we have found out very definitely where in the organism the mutation occurs, and we have discovered that, by modifying the environmental conditions in certain ways, mutations may be caused to take place more frequently than otherwise. The mere fact that we have discovered this much encourages us to believe that in the future we may understand more fully the causes of mutation.

Summary: Although opinions differ, it is generally felt that the most significant factors in bringing about evolution are mutation and natural selection (among the mutants). This interpretation, however, should not be accepted to the exclusion of all other theories. It is more than likely that the operation of Lamarck's scheme has in the past contributed in a very real way to evolutionary progress. Isolation and hybridization also play their parts, but are effective only after mutation has already taken place.

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in plants and animals many characters which clearly serve to adapt the organism to the environment, and there is the best sort of evidence that these characters are old mutations, that they have been added to the organism by mutations that have taken place some time in the past Hence one feels reassured in saying that, directly or indirectly, mutation, followed always by natural selection, has been the phenomenon underlying the bulk of evolutionary change and progress.

VIII

INFLUENCE OF THE EVOLUTION IDEA

It is safe to say that the study of evolution has revolutionized human thought. Every subject is now being considered from the standpoint of its evolution. Not only do biology and the physical sciences present their results from the standpoint of evolution, but the evolution of language, of society, of government, of religion represents the present method of investigation and presentation in all these subjects.

INFLUENCE OF THE IDEA OF INORGANIC EVOLUTION

The idea of evolution has been a conspicuous influence in astronomy. We no longer think of the solar system merely as consisting of a central body about which planets travel at various distances, but rather as the result of a succession of events, following one another in inevitable sequence. In other words, the solar system is thought of not so much as a fact, but as the result of a physical evolution. To understand the solar system is not so much to observe its present condition as to realize the series of changes that have led up to the present condition, and the possible changes that are yet to come. This evolutionary point of view sees in every present situation the suggestion of both history and prophecy. When astronomy carries us beyond the solar system into the infinite spaces, there are presented to us glimpses of all stages in the evolution of the physical universe.

The same point of view controls the work on earth

structure as presented by geology. The significant thing is not so much what the earth is, but how it came to be what it is. Its present structure cannot be understood without some knowledge of the changes which have brought it about. We have long recognized that the superficial features of the earth were not "created once for all," but are in a continual state of flux. The recorded history of any region of the earth's surface includes many changes. The "everlasting hills" may be a phrase true enough when the comparison is with human life, but these same hills were evolved and subsequent evolution will change them. When the recorded history of the earth is presented by geology, both as to its surface configuration and its vegetation covering, it is recognized to be a history of continual change, just as human history is a record of continual change.

INFLUENCE OF THE IDEA OF ORGANIC EVOLUTION UPON BIOLOGICAL SCIENCES

The influence of the idea of organic evolution is more extensive in its application than the idea of inorganic evolution, for it deals with life and all of its expressions. Its importance in the development of the biological sciences cannot be overestimated. The result has been not only an increased knowledge of the various aspects of biology, but also enormously important practical applications of this knowledge. A few illustrations will be given of how the evolution idea has influenced biological investigation.

The oldest phase of biology was the classification of plants and animals. Classification was necessary first for convenience in organizing the vast amount of material. The first classification was purely artificial, as much so as the arrangement of words in a dictionary, or of entries in a card catalogue. For example, among plants, the major groups were herbs, shrubs, and trees.

This brought together forms entirely unrelated, and also separated near relatives. When the idea of evolution took possession of biology, it was evident that plants and animals must be classified on the basis of relationship, as indicated by resemblances and differences. From that time biologists specializing in classification have been constructing what may be called "family trees." Many families are now recognized, made up of closely related forms, evidently related to one another by descent. This same thought has also resulted in connecting the ancient plants and animals, known only as fossils, with those now living. The result is that we now have in organized form a history of the evolution of plants and animals, from their records in the most ancient deposits to the present time. As investigation becomes more extensive and intensive, there are often slight shifts in classification, based on increasing knowledge of relationships.

After classification, the study of plant and animal structures began to be developed. The whole purpose was to discover evolutionary relationships from a knowledge of structures. At first, before the microscope was invented, only gross structures could be investigated, that is, structures that could be seen with the naked eye. For example, the different forms of leaves, stems, roots, and flowers were investigated and compared. When the microscope came into use, this investigation of structures extended to the minute structures that make up the bodies of plants and animals, the cells and the tissues into which they are organized. These minute structures gave clues to relationships that gross structures could not, and resulted in much additional evidence of relationship by descent.

It was in this same connection that reproduction came to be investigated and put upon its evolutionary basis. With the help of the microscope the whole performance of the individual cells came into view. Per-

haps the most significant results in relation to evolution came from the study of embryology, which means the study of all the changes that take place from the egg to the mature body. In the course of the early development of the embryo, very frequently glimpses were obtained of the beginnings of structures that soon disappeared, and were not represented in the mature plant or animal, but were present in some other plant or animal. It was natural to conclude that this indicated relationship. The main stimulus of the extensive work in embryology has been to discover relationships which will help to complete the story of the evolution of plants and animals.

Even a more important result than any of those mentioned has been the application of the evolution idea to the study of heredity. The experimental study of heredity is known as "genetics," and this important subject owes its origin and development to the evolution idea. The laws of inheritance have such a wide application in human interest and in the practical handling of plants and animals that this debt to evolution cannot be overestimated.

It is evident, therefore, that the evolution idea has been the great stimulus to investigation in physical and biological sciences, and that our great progress in these important fields began when the thought of evolution took possession of scientific men.

The influence that our knowledge of evolution has exerted upon biological sciences is not limited to the purely theoretical aspects of those sciences. Biology has a number of very practical applications, and, in the field of these practical applications, our knowledge of evolution can often be applied in a very practical way. Most conspicuous, perhaps, is the contribution which evolution makes to agriculture through improvement in the methods of breeding our cultivated plants and domesticated animals.

It has already been mentioned how the study of evolution culminated in the science of genetics. Genetics, the experimental study of heredity, may be regarded as the most modern method of studying evolution. The subject matter of genetics, therefore, is very properly a part of our knowledge of evolution. What we have learned of genetics has taught us how to breed our cultivated plants and domesticated animals in the most efficient way.

The possibility of improving our cultivated plants and domesticated animals has been brought out in some of the previous chapters. We know that in past centuries man has accomplished a great deal in this line. Man originally started to practice agriculture upon those wild types of plants which nature provided. These plants were not particularly suited to man's needs, but were simply the best types that were available at that time. As time went on, however, man found it possible to change the characteristics of these plants so that they became much better suited to his needs. In other words, an evolution of the cultivated plants commenced to take place. In bringing about this evolution, the same general forces were in operation as when evolution takes place in nature.

Now we have seen how, in nature, progressive evolution is brought about through the operation of natural selection. Generation after generation the only individuals which are allowed to survive and reproduce are those which are the best adapted to nature's requirements. In this way a gradual progress is effected in the direction of more perfect adaptation to nature's requirements. It was according to exactly these principles that man changed his cultivated plants. Generation after generation the only individuals which he would use for seed were those which were the best adapted to his own needs. In this way a gradual progress was effected in the direction of more perfect

adaptation of the cultivated plants to man's needs. The same general forces are in operation in both cases, but, since the standard for selection is different, it follows that the direction in which progress is made is also different. Nature, who is the selecting agent in the one case, perfects her plants toward a better adaptation to the natural environment; man, who is the selecting agent in the other case, perfects his plants toward a better adaptation to his own needs. In the one case we have natural selection, and in the other case "artificial selection."

Just how much man has already accomplished in this way can be appreciated when we contrast our present cultivated varieties of plants with the wild natural varieties from which they have descended. In most such cases the difference is so great that we would probably refuse to believe that the present cultivated variety is in any way related to the wild ancestral type, if we did not actually know that this was the case. Probably the most striking instances of this appear among that group of plants which we commonly refer to as "vegetables." In one famous case, mentioned previously, man has derived from a single wild ancestral type the cabbage, kohlrabi, Brussels sprouts, cauliflower, kale, and collards. These types differ widely from one another, and all differ from the ancestral type which is still growing wild in some regions. This is merely one of many possible examples. Similar "miraculous transformations" might be found among our cereals and fruits. Furthermore, what has been said of our cultivated plants applies as well to our domesticated animals, where, through this same policy of selection, enormous changes have been effected in the course of the past few centuries of stock raising.

One can readily see, therefore, that much in the way of practical gain can be accomplished through artificially controlling the course of evolution in our culti-

vated plants and domesticated animals. It is evident, however, that practically all of what man has accomplished in the past has been without any knowledge of evolution. In a purely empirical way man adopted a sort of a "common sense" policy of selection, and reaped the benefits thereof, without at any time understanding why his selection was effective or what was the true evolutionary significance of the process. Since this is true, since man has made such enormous gains without any knowledge of evolution, how are we justified in claiming that a knowledge of evolution (especially heredity) is of great practical value in this field?

The answer is simply this. What has been learned from the study of genetics makes it possible to accomplish in a very efficient manner those same things which the untrained breeder of past centuries did in a rather inefficient manner. Since the breeder of the past did not understand the mechanism with which he was working, he proceeded in a clumsy manner and attained his objectives only after the lapse of a great many years of effort, a good part of this effort having been absolutely fruitless, owing to the numerous mistakes which he made. With exactly the same start, the trained geneticist of today would be able to get the same results with an expenditure of much less time, effort, and space. This means that the same results could be obtained at a much smaller cost, which is efficiency.

This further fact must also be quite evident. If, through training in genetics, the breeder of today can get the same results as before in a much smaller time, it follows that in a given period of time he can get more results. This is actually the case. During the past decade we have been reaping the benefits of selection at a much more rapid rate and in a much more wholesale way than ever before. In addition it can be seen that the field of selection has been enlarged and

that the results of selection today are more permanent and in several ways better than before. Although reliable figures are not as yet available on this matter, it is surely safe to state that the application of modern selection methods during the last decade has brought results which are worth many millions of dollars annually to the agriculture of this country.

The improvement in selection methods that has come with a knowledge of genetics is, after all, less striking than the improvement that has been effected in connection with another method of breeding. We have already considered how hybridization may bring evolutionary progress when the hybrid produced by a cross combines in itself some of the desirable characteristics from both parents. This same principle can be turned to great advantage by man. Through crossing two of his cultivated varieties of plants, man may produce a hybrid variety which is superior to either parent. In addition to the superiority which results from combining some of the desirable traits from both parents, hybrids frequently exhibit a size, vigor, and productiveness that is vastly greater than that of either parent. The mechanism which operates during hybridization is a very complicated one, and it requires a considerable training in genetics to be able to guide artificially the operations of this mechanism. Before the twentieth century, breeders only occasionally, and, we might well say, through a lucky chance, reaped some of the practical benefits of hybridization. During recent years, however, owing to the knowledge that we now have of genetics, the practical results from hybridization have been enormous.

From what has been said the reader can appreciate how a knowledge of genetics makes it possible for the breeder, in a much more efficient manner than before, to improve the quality and productiveness of our crop plants. By exactly the same principles it is possible

to develop certain additional types of wild plants up to the point where they are useful to man. In two other ways also these same principles are applied to great advantage. Owing to undesirable features of climate and soil, many large regions of our country have in the past been unable to support cultivated crops. Some of these regions have recently been made available through the development of new types of crop plants that are able to grow in a poorer soil or in a drier or colder climate than before. These things have been achieved through intelligent selection or hybridization. Again, a fact which many people do not fully appreciate is that practically all of our cultivated plants very often become the victims of very serious diseases. In such cases it is impractical to treat the individual patient as we do in human disease. Instead we merely attempt to check the spread of the disease through the application to whole fields of plants of certain fungicides which will kill the disease germs. But very often a treatment with fungicides is quite ineffective, as when the germs of disease inhabit the soil and cannot be reached by fungicides. Even where fungicides might be effective it is hopeless to apply them thoroughly to crops grown on such a large scale as our cereals. In such cases we are helpless in checking the ravages of disease, and our only recourse is to develop, by selection or hybridization, new types of cultivated plants which are naturally resistant to the attacks of these diseases. These illustrations show how wide a field it is in which we can reap the benefits from applying our knowledge of genetics. Much has already been accomplished along these lines, not only with cultivated plants but also with domesticated animals. Much more will undoubtedly be accomplished during the next few decades.

Another very practical field of biology in which enormous benefits have been reaped from knowledge

of evolution is the field of human medicine. Since we know from our study of evolution that man is a descendant of the lower animals (though not a descendant of the present-day monkeys), we become assured that the structures and functions of man are laid out on the same fundamental plan as in the lower animals. It is possible, therefore, to conduct certain experiments upon lower animals and in that way to make certain important discoveries that are applicable to man. This practice, popularly known as "vivisection," has been attacked violently by certain blind individuals who must have failed utterly to appreciate the true values of the situation. It is undoubtedly true that the lives of many of these same individuals, or at least the lives of persons dear to them, have been saved time and again through a medical knowledge which has been made possible only as the result of those experiments upon lower animals which they condemn so ruthlessly. Surely it is obvious that the marvelous skill of the trained surgeon and his frequent "miraculous" successes have been made possible only through a most intimate knowledge of the bones, muscles, blood-vessels, nerves, and other tissues of the human body; and further, that this knowledge of the tissues of the human body is founded in good part upon the investigation of tissues in the bodies of lower animals, where the general structural plan is the same. Even more significant than structure is the matter of function. It is mainly experiments upon living animals that have taught us the final details of function in the various organs of our own body. Not only the surgeon but the physician is dependent upon what has been learned in this way. Those many "medicines" which are so useful in administering to our health have been "tried out" in the first place upon lower animals, and it is only through this means of approach that it has been possible to introduce many of them.

Perhaps the most effective way of emphasizing these points will be to present a single striking (but quite representative) example. This is an account of merely one of the many successes of one of our eminent surgeons. It illustrates how intelligent operations upon the human brain have become possible through a study of the brain of lower animals, through discovering that there are always certain definite areas of the brain which govern the activities of the muscles in certain regions of the body.

(Quotation from Dr. W. W. Keen, Surgical and anatomic evidence of evolution. Science 55:603–610, 1922.)

"A young woman with epilepsy, in whom the attacks were constantly increasing in frequency and violence, insisted that her attacks always began in her left thumb, then spread to the hand, then to the arm, followed by unconsciousness and violent convulsions all over the body. Careful observation for two weeks in the hospital confirmed her statements that the fits always did begin in this left thumb. If, then, I could prevent the fit from beginning in this thumb, so I reasoned, it might be that I could prevent the entire attack. Just as, in a row of bricks standing on end, if I can prevent the first one from falling, none of the others will fall.

"The possibility of the exact localization of the little cube of gray matter on the surface of the brain, dominating all the muscles of the thumb, was the key to the whole operation. This localization of the thumb center had been made absolutely by experiments on the brains of animals. Accordingly, I opened her skull, identified the spot corresponding to the thumb center (i.e., the great toe of the fore foot) in animals, and cut out a small cube less than an inch on each side." After the operation, the epileptic attacks of the patient, which before had occurred almost daily, recurred only

about once in a year, and she recovered from the operation without any bad after effects.

An enterprise of vast practical importance, which quite properly may be regarded as one of the applications of biology, is the matter of human breeding. The prospect of better human breeding has been clearly appreciated by but few persons, and in the nature of the case there has been very little done to date in the way of actively controlling this situation. There can be absolutely no question, however, but that man is subject to those same laws of evolution and heredity which operate upon the lower animals and plants. We have already observed how in nature there takes place a gradual progressive evolution of animals and plants, with the general result that these organisms become better adapted to their environment. We have also seen how man may take an active part as agent in the process, and may so direct the course of evolution in his domesticated animals and cultivated plants that these forms become much better adapted to his own needs. Since evolutionary progress is possible with lower animals and plants, it must also be possible with man; and since an intelligent control of the direction of evolutionary progress is possible with lower animals and plants, this also must be possible in the case of man.

An intelligent control of the direction of human evolution can be exerted in two general ways. In the one case man can play a rather active part as the selecting agent; in the other case he can assume a relatively passive rôle and let nature do the selecting more or less under his supervision. Much in the way of real practical progress can be brought about in either way. It is appropriate that we should all understand these two methods of controlling human evolution, and that we should all exert our influence toward furthering the proper application of both methods.

The "active" method is where man takes upon himself the responsibility of deciding that certain "desirable" individuals shall reproduce, and that certain "undesirable" individuals shall not reproduce. On the face of it the results of such a policy are bound to be good, for it leads to a multiplication of the desirables and an elimination of the undesirables. On the other hand, it is quite evident that this policy could never be applied in any very thoroughgoing way, not only because man would violently resist any such radical restriction of his personal liberties, but also because as yet no one is well enough informed to take the responsibility of intelligently controlling this enterprise. As yet it is only within very narrow limits that this policy is practicable, really only in connection with those cases where we can say beyond the shadow of a doubt that certain individuals are a menace to society and should not be allowed to reproduce their kind. The active control of human breeding should be exercised only after we have developed a thorough understanding of the subject with which we are dealing.

This enterprise of exercising an active control of human breeding represents the subject of "eugenics." Eugenics quite properly devotes itself to a twofold task: (1) learning more of the facts and principles of heredity in man; (2) devising the proper means of applying the knowledge so gained to the active control of human breeding. The second phase always follows the first; application is attempted only in cases where we are quite certain of the critical facts.

The first task of eugenics, that of learning the facts of heredity in man, is a great deal more difficult than might at first appear. During the last two decades geneticists have learned a great many of the facts of heredity in some of the lower animals and plants; but what has been possible for these lower organisms seems well nigh hopeless in the case of man. There are sev-

eral reasons for this. First and foremost is the fact that we can experiment upon lower animals and plants, controlling their matings and the conditions under which they live. This is out of the question in the case of man. In addition to this, man is, after all, an exceedingly unfavorable type of material in which to study heredity. The generations are far apart, the number of offspring from any given mating is very small, and the great complex of different characters contained by any single individual is extremely confusing as compared with those lower animals and plants that have been used so successfully in the study of heredity. How then is it possible to learn anything about heredity in man?

Although extremely difficult, this task is not impossible. In the first place, one can benefit by what has already been learned of the principles of heredity in the lower animals and plants. Knowing these principles in advance, one can quite often interpret situations in man which are due to the operation of these same principles. Then, lacking experimental data, one consults the only data that are available, that is, family pedigrees. These family pedigrees are studied through as many generations back as reliable records have been kept, and in this way the method of inheritance of quite a number of characters has already been discovered. The great difficulty, of course, lies in the fact that the characteristics of one's ancestors are seldom recorded in any very exact way, and it is only when an absolutely exact record is known that such data can be used. About the best records that are available are those that have been preserved by some family physicians, for in these cases the accounts are usually in a very exact and scientific form. For the most part, however, it is only matters of disease and abnormality that physicians have concerned themselves with. It is not surprising, therefore, that we have a much more

exact knowledge of the inheritance of abnormalities than of the "normal" characteristics of man. All in all it can be seen that there is an enormous amount of labor involved in learning the facts of inheritance in man.

Work of this sort has been going on for several years, and is still being carried on very actively under the supervision of the Eugenics Record Office, Cold Spring Harbor, N. Y. Although there has as yet been only enough time to scratch the surface of this vast subject, there is already available a great body of information bearing on the inheritance of various of the characters of man. Although the indications are rather clear that some desirable characters (such as special abilities of one sort or another) are heritable, the exact mode of inheritance in such cases is not well understood. Undoubtedly it will be many years before we are ready to provide any very certain recommendations upon methods of producing superior individuals through a combination of the characteristics of two "desirable" parents. After all, there is no great urgency for this "positive" application of eugenics, and we could expect in this matter no very general cooperation on the part of the public.

Much more, however, is known about the inheritance of certain undesirable characters. Not only do we know that such things as feeble-mindedness, insanity, etc., are heritable, but we understand the exact mode of inheritance of these traits. In other words, we are ready to provide very definite recommendations as to methods of eliminating from society certain types of inferior individuals. This may be regarded as the "negative" application of eugenics, the purification of the human race through an elimination of undesirable types. Since there is great urgency for this negative application of eugenics, we do expect in this matter not only a sympathetic but an enthusiastic cooperation on

the part of the general public. Already a certain amount of this cooperation has been obtained, and as a result there have been enacted in a number of states laws requiring the segregation or sterilization of certain undesirable types, so as to prevent the further multiplication of individuals of this sort. Much good will undoubtedly result from these measures. Much more good will come in the future when our laws governing these matters are more complete.

It is hoped that this brief account will provide the reader with some conception of the eugenics enterprise. It is also hoped that the reader will cultivate an intelligent sympathy for this enterprise. A word of caution might be well, however. An unrestrained enthusiasm is likely to do such a cause more harm than good. Matters of this sort cannot be rushed. We must not attempt application until we are certain of our facts; and we should not attempt to impose an application upon a relatively unsympathetic public. A more general education on these affairs will be profitable.

After all, however, our original object was simply to point out to the reader one of the important practical applications of our knowledge of evolution. Surely it is evident that eugenics depends entirely upon a knowledge of heredity. Our knowledge of heredity has come as a natural outgrowth of the study of evolution, and is properly a part of that more general subject.

The hope of intelligently controlling the direction of human evolution rests not entirely with eugenics. Following the program of eugenics, man plays a relatively active rôle as agent in the selection of those individuals which are to survive. Side-by-side with eugenics, however, there should be put into application another method of controlling human evolution. In this latter method man assumes a more passive rôle, merely allow-

ing natural selection to take her course under his supervision.

If man were living in the same "wild" environment as the lower animals, natural selection would doubtless operate to modify him in the direction of great physical strength and powers of resistance. These features would be more perfect adaptation to a wild environment. Man of today, however, is living in quite a different environment, a "civilized" environment, in which the most prominent and exacting demands are those which arise from his continuous and varied contacts with other human beings. In such an environment the most important features of perfect adaptation are not mere physical strength, but consist instead of various types of mental power. Industry, enterprise, courage, sagacity, etc., are what are required of man to adjust himself effectively to the conditions of life that surround him.

Now it is quite certain that natural selection will be in operation to eliminate the more poorly adapted individuals and preserve the better adapted, and it is inevitable that some sort of evolutionary progress will result. But are we sure that this is the right sort of evolutionary progress? Are we sure that it is operating in the direction of producing "better citizens" and a better society? As has been pointed out in some of the preceding chapters, we may be confident that we will move in the right direction if society is organized on sound political, economic, and educational principles. Under those circumstances the "good citizens" will usually survive and the bad citizens perish. But under unsound political and economic systems it is quite possible that a premium may be put upon greed, injustice, and dishonesty. Under such circumstances the greedy, the unjust, and the dishonest individuals will be successful in life. These will be the "fit" under such a system, and human evolution will inevitably operate

to multiply such individuals and exaggerate such traits. Further, under an unsound educational system many of the truly desirable individuals will have no opportunity to express their desirable traits, and the important influence which they should be exerting upon the improvement of society will be lost when these individuals are themselves lost in obscurity without reproducing their kind. How important it is to establish and preserve sound political, economic, and educational systems! How impressive and how practical is this lesson on human progress which comes from our knowledge of evolution!

INFLUENCE OF THE IDEA OF ORGANIC EVOLUTION OUTSIDE THE REALM OF BIOLOGICAL SCIENCES

All human problems are in a certain sense biological. The evolution idea, therefore, has a wider application than its use in guiding investigation in the physical and biological sciences, and in applying the results of such investigation to human needs. The principles of evolution have perhaps not been applied as fully as they deserve to be in the interpretation of the problems presented by history, political science, sociology, economics, etc. Evolution indicates that certain conditions and their results are inevitable, and that progress in any desired direction is possible. Training in the analysis of situations and in the recognition of conditions of desirable progress is certainly supplied by a study of evolution. A few concrete illustrations will help to make this possible application of the evolution idea more obvious.

Racial problems are becoming more and more pressing as the races of men are being brought more in contact. In the old days of race isolation there were no such problems, but complete isolation is no longer possible. Races inevitably come into commercial and political contact, but the problems are particularly

acute when all the races are mingled in one government, as in this country. Racial groups may be considered as organisms, and their reactions to one another are as evident as are the reactions of plants and animals in the evolutionary program. There is conspicuous a struggle for existence, the gradual adaptation to conditions, the survival of those that become better adapted, the gradual elimination of those that do not become adapted. Even the "friendly" struggle between racial groups results in natural selection. It will all depend on the basis of this selection, and the evolution idea suggests that this basis must be one that makes for better human relations. The evolution program will be inevitable, but what may be called the evolution motive may be controlled.

The evolution program can be observed also in connection with political groups. They are constructed for struggles, and in this case adaptation to the desires of those who determine such issues will have the usual result. As issues shift, adaptations shift, and progress in a given direction may not be constant. The principle of natural selection is exemplified nowhere more clearly than in the struggle for existence among political groups, and when these groups multiply, the final adaptation selected may not be very conspicuous. For this reason, political progress may be very slow, or selected adaptations may even result in retrogression. In any event, progressive evolution as a result of the struggle of political groups for existence is the thing to be secured, even if it is very gradual.

The problems involved in the struggle of economic groups are even more acute than those connected with political groups. Certain economic groups may be defined as institutions representing commercial units. We recognize that they are competing institutions, and that their struggles with one another are based upon the desire to be "selected." Every device used has this

bid for selection in view. In these cases, of course, there are many kinds of selection, but each one of them determines the survival value of some adaptation. The total result of this kind of struggle is probably better service, so that it may be expected to represent progressive evolution.

The economic classes of individuals, however, present more serious problems than the economic institutions. Such classes are represented by capitalists, farmers, laborers, professionals, etc. The struggles for existence among these classes are well known, and the resulting selection has sometimes been in the direction of progressive evolution, and sometimes in the direction of retrogressive evolution. A better adaptation for one party to the struggle may be quite the reverse for another party, and the result is a retrogression. Natural selection, resulting in progressive evolution, must choose some adaptation favorable for both at once, for they are mutually dependent. It is for this reason that in such struggles often some disinterested party is asked to determine the best selection, the selection that will make for continuance and progress.

It is evident that in all human activities, represented by races, political groups, economic groups, etc., the evolution forces are present, and the evolution concept helps to interpret the results. The same is true of such intellectual enterprises as philosophy and psychology, whose representatives are notably evolutionists.

There remains to be considered another great field of human interest, and that is religion. So important is this subject, and so often misunderstood in its relation to evolution, that it will be considered in a separate chapter.

IX

EVOLUTION AND RELIGION

THE belief that science is antagonistic to the Christian religion was very general among church people of a generation or two ago. The accumulating facts of science, and especially various conclusions based upon the facts, were thought to contradict certain statements in the Bible. This attitude towards science in general became most outspoken when Darwin announced his explanation of evolution, for among the organisms involved was man, whose physical origin had been settled in the minds of the majority of Christians by the plain statement of Scripture.

Gradually the situation changed, and the hostile camps became allies in a great cause. Religion discovered that science is honestly searching for the truth, and science discovered that the Christian religion has a scientific basis. It seems strange now that the two groups, each searching for the truth in its own way, should ever have come in conflict. Truths are not contradictory; if claimed truths are contradictory, then the truth is not clear.

When it is said that the situation has changed, it is not implied that all of the representatives of religion and science have declared an armistice, for in certain localities and with certain temperaments the old notion of the incompatibility of science and religion persists But these are mere "hold overs" from a former general situation. The whole tendency today is toward the cooperation of religion and science.

The first thing to make clear is that the impression that science and religion are in conflict arose from the confusion of religion with theology. In a certain sense theology may be called a science, the science whose subject is God, and the great body of whose literature is the record of men's conclusions concerning God, which may fairly be called philosophical speculations. That such speculations have developed great diversity of opinion is evidenced by the existence of numerous church denominations. In the midst of clashing theologies, however, religion remains the same, for it deals, not with speculation, but with human character, and its measure of character is conduct. If in their search for truth scientific men now and then discover facts that contradict certain conclusions of a speculative philosophy, they cannot be regarded as attacking religion. About all there has been to the so-called conflict between science and religion is the setting of a discovered fact over against a speculation.

The thoughtful Christian certainly appreciates the fact that the presentation of his religion must be adjusted to the increasing body of scientific truth. To hazard religion upon the issue involved in denying matters of definite experience is not to be thought of. In a scientific age the result would be to alienate the increasing thousands who have come in contact with science, and to convert a powerful and helpful influence into a serious obstruction. It matters little what scientific theories are abandoned or withdrawn. They are certainly never withdrawn because of ignorant opposition, but only because of advance in knowledge. If an hypothesis is false, it will come to naught, and if it is true, no amount of opposition can withstand it.

The subject of organic evolution has aroused more opposition from certain representatives of religion than has any other scientific subject. In the minds of the uninformed Darwin's name seems to be the only one

associated with this field of investigation, and to them evolution and Darwinism are synonymous. In the preceding chapters it has been shown that there were theories of evolution before that of Darwin, as well as others since. It so happened, however, that Darwin's theory was announced at the psychological moment for developing a conflict with theology, and so his name became identified with this conflict. In the recent revival of this old conflict, we are hearing again that evolution is anti-Christian. The most obvious fact to one who believes in both evolution and Christianity is that there is an entire misunderstanding as to the facts and claims of evolution as it has been developed by the more recent work. Such a misunderstanding has been corrected in the preceding chapters, which give an outline of the attempts to explain organic evolution. One notable misconception may be easily understood. As facts multiplied, the current explanations were found to be inadequate to explain some of them. For example, the more intensive study developed the fact that Darwin's explanation was not satisfactory. His name is so identified with evolution in public thought that the criticism of his conclusions was taken to mean that the theory of evolution was being abandoned. The real situation is that every proposed explanation may prove inadequate, and yet the facts of evolution remain to be explained.

It is very instructive to realize the revelations made in recent years by physics and chemistry as to the constitution of matter, and the natural laws that have brought about such stupendous results as solar systems, earth structures, etc. This kind of evolution, working through an extent of time and space almost impossible to realize, does not seem to have aroused any antagonism. It was in connection with organic evolution that the theological mind became sensitive. It seems reasonable, however, to infer that if inorganic evolu-

tion is simply the method by which God moulds matter, organic evolution could be regarded as the method by which God develops organisms. In other words, it is all the result of the activities of that all-pervading energy which we have learned to call God. There is no religious difference between creation by law and creation by direct command, if back of it all the Creator is recognized.

The fact of progressive evolution is most impressive in this connection. For example, we have observed that through all the stretch of earth history, in spite of all imaginable changes in external conditions, certain structures in plants and animals have changed steadily in one direction. These steady changes have carried forward the group as a whole. When we apply this to the human situation, progressive evolution depends upon what may be called human selection. This selection determines whether there shall be progress or not. Human selections of all kinds have been made, but there has been much progressive evolution. It is the function of religion to guide human selection, so that there may result a steady social progress. This fact of steady progress appeals to the Christian, who feels that under the guidance of his religion there will be a progressive evolution of humanity.

The conclusion of the whole matter is that since evolution is an established fact it cannot be anti-Christian. The alternative need not be considered, for it is just as clear that Christianity has a scientific basis in the nature of man, and that its results have been demonstrated as clearly as those of experimental evolution. The fact is that these two great fields, so far from being contradictory, are mutually helpful. In this way the revelation of God in Nature has supplemented his revelation through Christ.

Nothing is more helpful to the student and leader of men than a clear application of the working of evo-

lution as exemplified in plants and animals. Evolution teaches that progress is gradual; that a better is progress toward the best; that the future has its roots in the present. It shows that advance in a certain direction may not be uniform, for there are periods of apparent retrogression, as well as those of more rapid advance. The results are only apparent in the large view over periods of time, when the tossing back and forth of surface waves disappears, and the steady advance of the slow-moving current becomes apparent.

It is the Christian claim that God has revealed himself to man not merely in the words of Scripture, but also in the works of Nature. It would seem likely, therefore, that the revelation of Scripture is supplementary to that of Nature, containing further but not contradictory revelation. It would seem more logical, therefore, to read our knowledge of Nature into our interpretation of Scripture, than to interpret Nature by our conceptions of Scripture. The frequent attempts to interpret natural phenomena by conceptions derived from Scripture have so often ended disastrously that a reversal of the process might be suggested. That these disasters do not involve the Scriptures simply demonstrates that the conclusions were unessential.

As an illustration, it might be cited how common and painful were the efforts to show the perfect adaptation of everything in Nature. The most trivial anatomical parts of plants and animals were held to be perfect, in the sense that they could not be better adapted to the work at hand. Since it has been found that there is no such thing as perfect adaptation among organisms, and furthermore, that perfect adaptation means stagnation, for it removes the essential factor in progress, not only have the old views been corrected, but a very large and new thought has been introduced.

Though absolutely perfect adaptation has never yet been achieved by living organisms, progress toward

more perfect adaptation has been the evolutionary keynote of all bygone ages. At all times the hope and possibilities of still greater progress toward perfection have furnished the activating principle for all forms of life. Endowed at the beginning of life with an equipment which functioned imperfectly, each living organism possesses capacities for perfecting that equipment with which the needs of life may be met. The same is seen on a more magnificent scale in the age-long histories of great groups of plants and animals. Endowed at the beginning with an imperfect equipment, each race of organisms has possessed capacities for unlimited progress toward perfection, and the progress of the race has been built upon the progress of the individuals. Of all living organisms, man alone can be fully conscious of these possibilities. Man alone can consciously direct the line of progress, and, through the lives of successful individuals, make certain progress toward a goal of perfection.

The reason why so many scientific men believe in Christianity is that they find it to be thoroughly scientific. What can be called a scientific approach to religion may be outlined briefly as follows.

Religion is now known to be a universal human impulse. No race of men of any age of the world failed to give expression to this impulse. Any universal impulse must have some function. The function of the food impulse, for example, is to keep us in health and vigor. It seems obvious that the function of the religious impulse is to develop the greatest efficiency, to bring man to the highest expression of his being. The resulting efficiency all depends on the ideal selected. If there is an unwise selection in regard to the food impulse, the result is unhappy; and so if there is selected an unwise ideal in response to the religious impulse, the result is far from efficiency.

The effective ideal has been demonstrated by gen-

erations of human experience. Man is a bundle of impulses, some of them base, some of them noble. Not all of them can dominate. Which one shall be selected to dominate? This selection determines a man's religion. The baser impulses can be dismissed as out of consideration when we are selecting a religious ideal. The problem is to select among our nobler impulses the one that shall determine a decision when conflicting interests are involved.

If we try to discover the dominating impulse selected by those whose lives we admire most, those about whom we read, and also those whom we know, we find that they have selected unselfishness to dominate their lives; unselfishness that expresses itself in service. It is the most difficult possible selection, for it runs counter to most of our other impulses. But it makes the difference between a self-centered life and an outgoing life. Men can be put into two categories: those who are centripetal (self-centered), and those who are centrifugal (outgoing). There can be no question as to which category is the more efficient.

The next step is to discover the stimulus that will secure response to an impulse so difficult to keep functional. It is clear that the most masterful human passion, and therefore the most powerful human stimulus, is love. We realize that everything that is finest in human character and conduct is in response to the stimulus of love. Our conclusion is that the most effective ideal for the religious impulse is *love stimulating service.* This is the ideal of the Christian religion, and it makes scientific men choose it as the only religion with a scientific approach, no matter how much theologians, and rival church organizations, and professing Christians may confuse the issue. Furthermore, since it has selected our most masterful passion as the stimulus, it is the final religion.

The great contribution which Jesus made to religion

was his recognition of the master passion love as the most powerful stimulus to develop the best that is possible in man. It is no wonder that in the religion of Jesus, God is not only called Father, but is personified as Love. God is Love, that is, the master passion that can develop the best that is in us.

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